9950-829

(NASA-CR-172970) COST ANALYSIS OF AN AIR BRAYTON RECEIVER FOR A SOLAR THERMAL ELECTRIC POWER SYSTEM IN SELECTED ANNUAL PRODUCTION VOLUMES Final Report (Pioneer Engineering and Mfg. Co., Inc.) 76 p

N83-33333

Unclas

G3/44 28577

PEM

ONE SOURCE ENGINEERING

PIONEER ENGINEERING

AND MANUFACTURING COMPANY

DIVISIONS:

- WETTLAUFER
- INDUSTRIAL
- RESEARCH AND DEVELOPMENT

2500 EAST NINE MILE ROAD • WARREN, MICHIGAN 48091 • TEL. (313) 755-4400

FINAL REPORT

COST ANALYSIS OF AN AIR BRAYTON RECEIVER FOR A SOLAR THERMAL ELECTRIC POWER SYSTEM IN SELECTED ANNUAL PRODUCTION VOLUMES

December 18, 1981

Prepared for

JET PROPULSICN LABORATORY
4800 OAK GROVE DRIVE
PASADENA, CALIFORNIA 91103

Prepared by

Pioneer Engineering & Manufacturing Company
2500 E. Nine Mile Road
Warren, Michigan 48091

JPL Contract 955791
Modification No. 2

Pioneer Work Order 20895

TECHNICAL CONTENT STATEMENT

ABSTRACT

Pioneer Engineering and Manufacturing Company estimated the cost of manufacturing an Air Brayton Receiver for a Solar Thermal Electric Power System as designed by the AiResearch Division of the Garrett Corporation. Production costs were estimated at annual volumes of 100; 1,000; 5,000; 10,000; 50,000; 100,000 and 1,000,000 units. These costs included direct labor, direct material and manufacturing burden.

A make or buy analysis was made of each part at each volume. At high volumes special fabrication concepts were used to reduce operation cycle times. All costs were estimated at an assumed 100% plant capacity. Economic feasibility determined the level of production at which special concepts were to be introduced. Estimated costs were based on the economics of the last half of 1980.

Tooling and capital equipment costs were estimated for each volume. Infrastructure and personnel requirements were also estimated.

Cost reduction recommendations based on this design are included in the report.

The basic receiver design uses a large amount of Inco 625 in the heat affected areas. In an effort to reduce the cost of the receiver, Pioneer determined the degree of cost reduction that might be realized if NDS (Nitride Dispersion Strengthened) 410 steel were used in place of Inco 625.

The costs of plasma coating the heat affected areas of the receiver were studied.

ACKNOWLEDGEMENTS

Cost studies such as this are critically dependent on vendor cooperation in the supplying of material cost at the various volumes. Pioneer would like to extend its appreciation to Mr. John Krauger of the Johns-Manville Company, Mr. James Crouse of Huntington Alloys, Mr. Tom Bright of Wall-Colmonoy of Detroit, Michigan, Mr. Robert Maddelein of Ipsen Industries, and Mr. Sam Bianchi of Livernois Engineering, Detroit, for their efforts and cooperation in supplying costs and technical data.

We would like to extend thanks to Mr. Herbert Fortgang, Technical Manager of this project for JPL, for his technical assistance in the progress of this activity.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

OBJECTIVE

This study has two primary objectives.

The first objective was to develop accurate manufacturing cost numbers for an Air Brayton Cycle Receiver as designed by the AiResearch Division of the Garrett Corporation in annual production quantities ranging from 100 to 100,000 units.

The second objective was to determine the degree of cost reduction that might be realized if NDS (Nitirde Dispersion Strengthened) 410 Steel was used in place of Inco 625. In addition, the study was to evaluate the cost of plasma coating the heat affected areas of the receiver.

MANUFACTURING COST STUDY
AIR BRAYTON CYCLE RECEIVER

This receiver is basically a heat exchanger receiving the focused sun's rays from a parabolic dish mirror solar concentrator. Air is heated in the receiver and then powers a Brayton engine which is coupled to an electric alternator/generator which produces electricity.

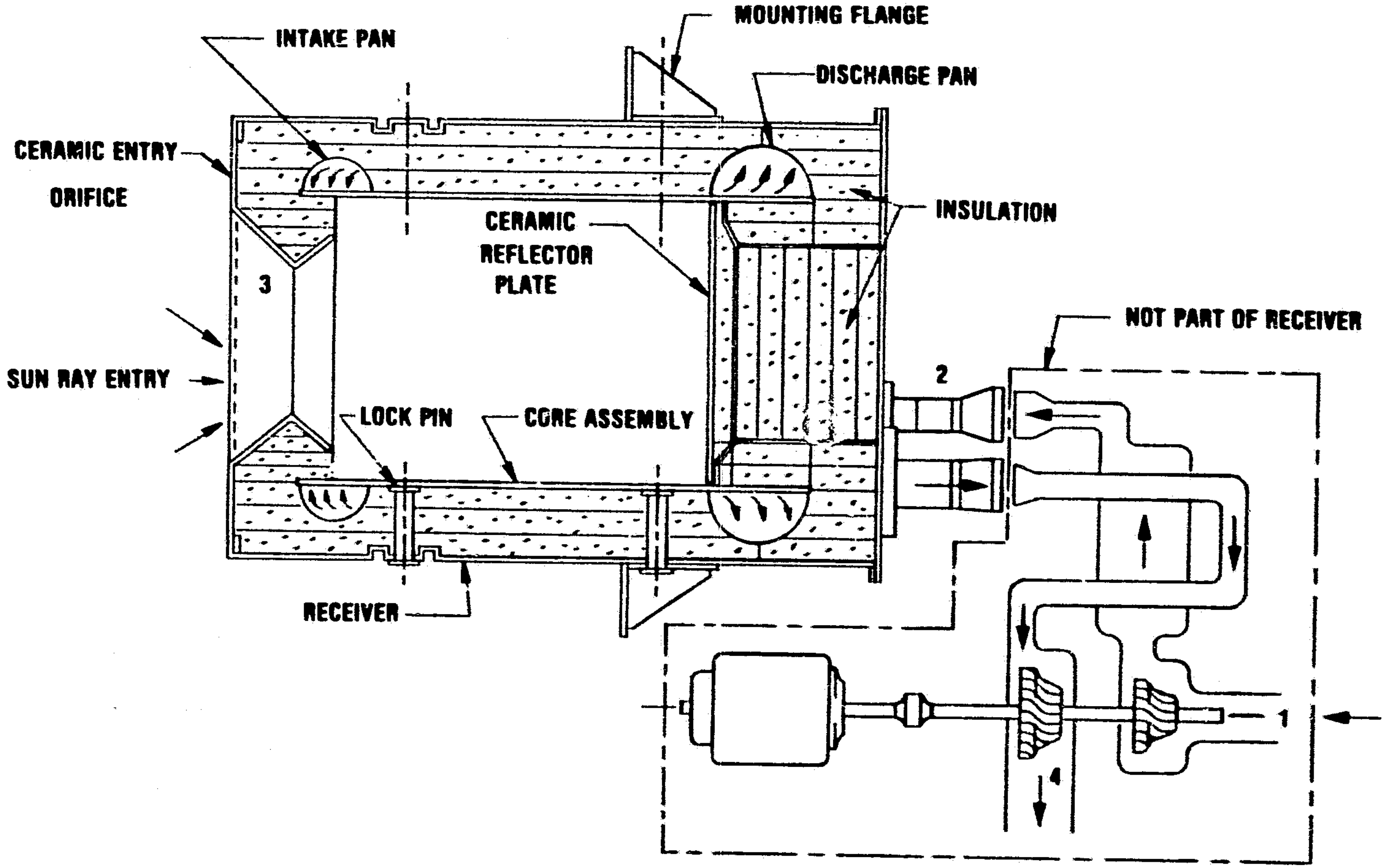
Figure 1 is a schematic illustration of the receiver system which is located at the focal point of a parabolic dish concentrator. The receiver is cylindrical in shape, 30 inches in diameter, 45 inches long and open at one end. It consists of two concentric cylinders with a five inch insulated annulus between them. High temperature heat resistant materials are used throughout. The receiver core is made of Inconel 625. Ceramic components are used for both the aperture and reflector plates.

The following describes the operation of the receiver: (See Figure 1). Incoming air enters the compressor at (1) flows through ducts (2) in the walls of the receiver. Entering the core, air is heated to approximately 1500°F by concentrated solar energy. The sun's rays enter the receiver through an eight inch diameter orifice in a molded ceramic plate (3). The heated air then collects in a "pan" (toroidal receiver) prior to being ducted to a turbine. The heated air expands through the turbine (4) and is then exhausted. The turbine then drives an air compressor and an electrical generator.

The receiver assembly is illustrated in greater detail in Figure 2. This figure shows the inlet tube as it is bent around the outlet pan and attached to the inlet pan.

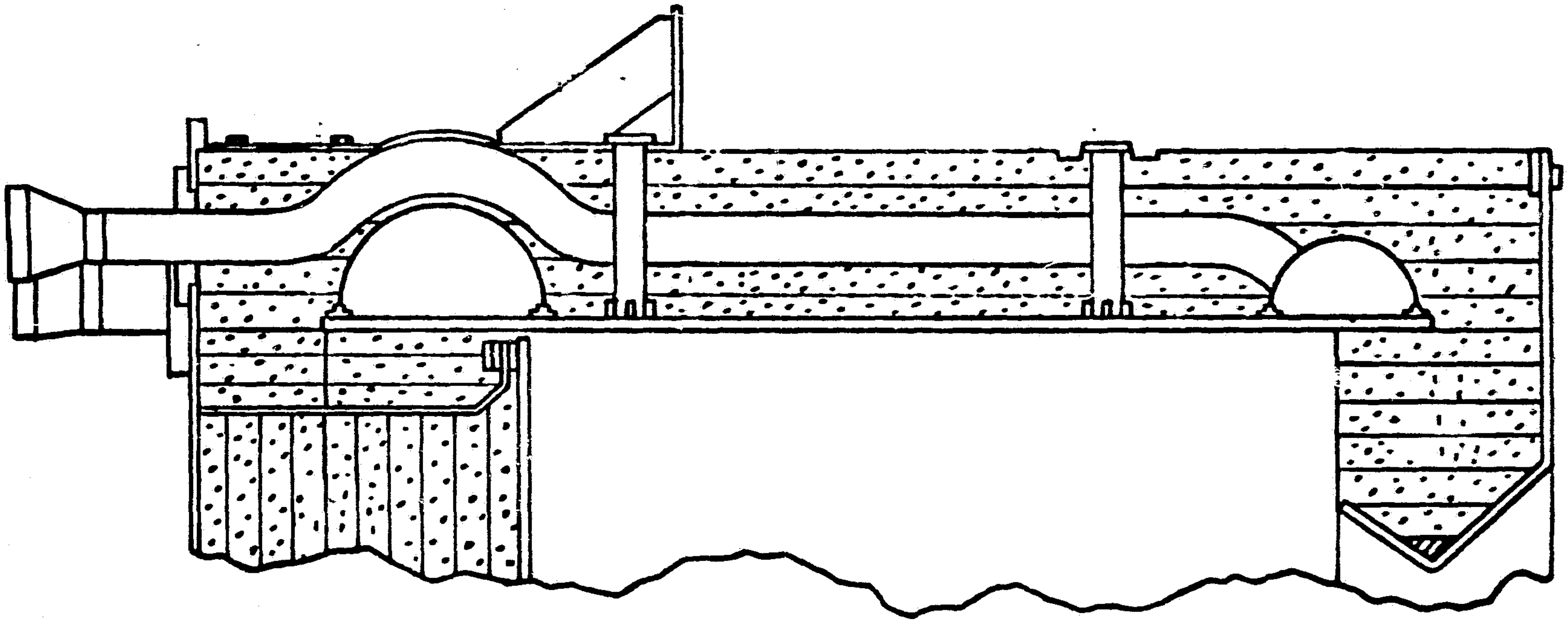
The estimated cost of manufacturing this Air Brayton Cycle Receiver in annual production quantities of 100; 1,000; 5,000; 10,000; 25,000; 50,000 and 100,000 units is reported herein. Included in the estimates are the costs of:

Material
Direct Labor Hours or Minutes
Direct Labor Dollars
Tooling Dollars
Capital Equipment Dollars
Burden Dollars



BRAYTON CYCLE RECEIVER SYSTEM OPERATION

FIGURE 1



RECEIVER ASSEMBLY-DETAIL

FIGURE 2

Each component part of the receiver was processed for each annual production volume. Wherever justified, the production method (Processing) was modified to reduce the production cost.

This report presents a manufacturing cost for the subject receiver. A selling price, or consumer cost, would result if the following were added to the manufacturing cost:

General and Administrative Expense
Distribution Cost
Profit

This report contains observations and data relating to the potential cost reduction of this receiver design.

COSTING PROCEDURE

The cost estimation of the Air Brayton Cycle Receiver was performed by examining detailed drawings, which were supplied by the AiResearch Company of California. This study evaluated the costs of:

- Direct Material
- Direct Labor
- Burden
- Tooling
- Capital Equipment

for annual production quantities of 100; 1,000; 5,000; 10,000; 25,000; 50,000; and 100,000 units. All costs are expressed in 1980 dollars.

Each receiver part, component, assembly (major and minor) and the final assembly was examined and evaluated to determine the cost of its material and the method of manufacture (process based on the particular annual production volume under review). In estimating the costs of receivers produced at the rate of 100 to 1000/year, it was assumed that many of the items would be purchased from small shops and then assembled in an in-house facility.

For production runs of 5,000 to 25,000 units/year, it was assumed that a make or buy decision would be made to obtain the lowest cost based on a trade-off of capital investment versus labor cost. Again, the assembly would be performed in-house. It should be noted that a production of 25,000 units per year requires that a receiver be manufactured every six minutes - based on a sixteen hour working day (two eight hour shifts).

As the production rate increases to 100,000 units/year it was assumed that most items would be made in-house with the necessary investment in tooling and capital equipment. Assembly and final testing would be performed in-house. This rate would require a receiver be produced every minute - based on an eight hour working day.

For low production volumes of 100 to 25,000 units/year, the receiver manufacturing costs are considered to be labor intensive, whereas the manufacture of receivers at higher production volumes would be capital intensive. This could result in lower unit costs for materials and labor. Estimates were also made for the probable cost of the tooling and capital equipment that would be required for each of the production volumes under consideration.

Make or Buy Decision

Each drawing was reviewed for a make or buy decision. All so called "standard" parts (catalogue, off-the-shelf items) were classified as "buy" upon the initial review. Vendor quotes were solicited for these items. Subsequently other items were added to the "buy" category based on the cost effectiveness of a "make" or "buy" comparison.

"Make" parts were analyzed for the characteristics that constrained their method of manufacture. As each characteristic was reviewed the equipment necessary to produce that characteristic was defined. Items such as material, hardness, part size and shape, tolerance, finish, were all considered in making a good equipment choice. These characteristics, considered in the light of the volume required, determined the number of operations, and the size and type of equipment required.

The general type of part to be produced was defined by the part print. The print specified whether the part was to be a structural section or weldment, a machined bar, a shaped plate or sheet, or whatever other material and shape was required by the design. The design as specified on the drawing was processed for manufacturing; the assumption was made that alternatives were considered by the designer before the choice depicted on the print was made. In effect, the part was costed as designed.

Volume Effect of Process Selection - The specific operation selected for producing a part to print is production volume sensitive. That is, the equipment required to perform a given operation will vary as the volume changes. As volume increases, more investment is justified in order to reduce the production time and hence reduce manufacturing cost.

Where high volume machining (and stamping) justified, special machines were conceived and costed.

The point at which a given equipment and tooling expenditure is justified is a function of the Return on Investment. ROI calculations for each part at each volume were beyond the capacity of this study. An acceptable approximation of the cost effectiveness of a given process at a given volume is the utilization of the equipment to be used. For this study, a given piece of equipment was considered acceptable if the utilization exceeded 25%. Though this arbitrary utilization is subject to debate, it was considered a viable compromise. This rule was used in applying methods to tools, die fixtures, material handling equipment, as well as machinery.

Inasmuch as the subject receiver is essentially a weldment, automatic (robotics) arc welding techniques were employed when the costs were justified. Processing these assemblies for costing required the conception of special fixtures and transfer mechanisms in conjunction with special features of programmable robots. These concepts were timed and the hardware cost estimated. Vendor quotes are not available for such concepts because of the proposal cost incurred. As a result such costs are estimated by the engineers working on the costing project.

Standard Time Derivation - An essential element in this costing is the application of standard times to an operation. In single station, one machine operations, this time includes unload, load, machine cycle time, and the application of operator allowances.

For multiple station machines, the load and unload times are generally internal to the cycle time of the machine; the cycle time is the time of the slowest operation (or station) plus the index time. The load and unload times are a function of the size, weight, and configuration of the part, as well as the design of the tooling. The estimating engineer must estimate these functions in order to arrive at the cycle time of an operation.

The "allowances" mentioned above account for two types of elements: those associated with the operation per se, and those related to shop operations. Those relating to the specific operation are personal time, tool trouble time, and instruction time. The shop operation allowance covers stock delay time, machine downtime, and off-standard materials.

In considering any metal working operation cost, a decision must be made regarding the number of operators required to perform the operation. This number can vary from 3 or 4 to as low as 1/10 men per operation. Direct labor costs are a product of the machine cycle per operation multiplied by the hourly rate and that fraction or multiple of a man assigned to the operation.

Direct Labor Cost - Direct labor is the product of direct labor rate, the operation cycle time, and the number of operators assigned to the operation. The determination of cycle time and operator assignment per machine have been discussed above.

In this cost study the direct labor rate used in labor costs reflects the employers out-of-pocket cost for the employees services. This includes the gross wages appearing on the employees check plus all of the fringe benefits earned during employment but not seen directly. These benefits include vacation pay, pension funding, hospitalization, medical, dental and optical plan costs, sub pay benefits, uniform allowance, and grievance time.

Burden Rate Derivation and Application - Burden costs are all the costs of operating a business enterprise over the cost of direct labor and material. Generally, these costs do not include the selling expense, profit, or interest expense on borrowed operating capital. They do include such traditional items as utilities, taxes, insurance, depreciation, all salaries and fringes, as well as the interest expense for money borrowed for the purchase of operating equipment.

There are different approaches to distributing (recovering) burden costs in a manufacturing facility. The simplest approach is to sum the costs over some period of time and determine their relation to the direct labor hours used. That percentage is then applied to the direct labor cost of a product to get the manufacturing cost. This technique is occasionally refined by collecting costs by department rather by plant. Rarely is a major machining center established as a cost center and its operating costs applied to the direct labor hours expended while working on a product.

Using each machine as its own cost center is the most accurate method for distributing cost. This technique is generally avoided because of the expense involved in establishing and maintaining the system. As mentioned above, burden rates are established by the historic accumulation of costs with no regard given to individual machine differences or general efficiency of operations. Poor operating efficiency has a tendency to raise costs, which are recovered from the customer as increased burden.

The burden costs used in this study were developed for each piece of machinery used in a manufacturing process. They are absolute costs per hour of operation - not percentages of other costs. They have been derived using nominal operating costs for a manufacturing facility, operating at nominal efficiencies.

Some of the major factors contained in the burden costs have been discussed above. The complete list contains all of the variable and fixed costs associated with the operation of a given piece of equipment in an average manufacturing environment.

In general, the method of Cost Analyses follows the outline shown in Figure 3.

Material Costs - Material costs as submitted in this report consists of -

1. Base material to produce "make" parts
2. Cost of "buy" parts - purchased complete

"Buy" parts consist of a variety of miscellaneous parts that were more economically produced by specialty houses. The costs of these parts was obtained by soliciting quotations from potential vendors. In some cases quantity purchases caused the price to decline; in many cases the cost was constant.

FLOW DIAGRAM

MANUFACTURING COST ANALYSIS

PIONEER METHODOLOGY

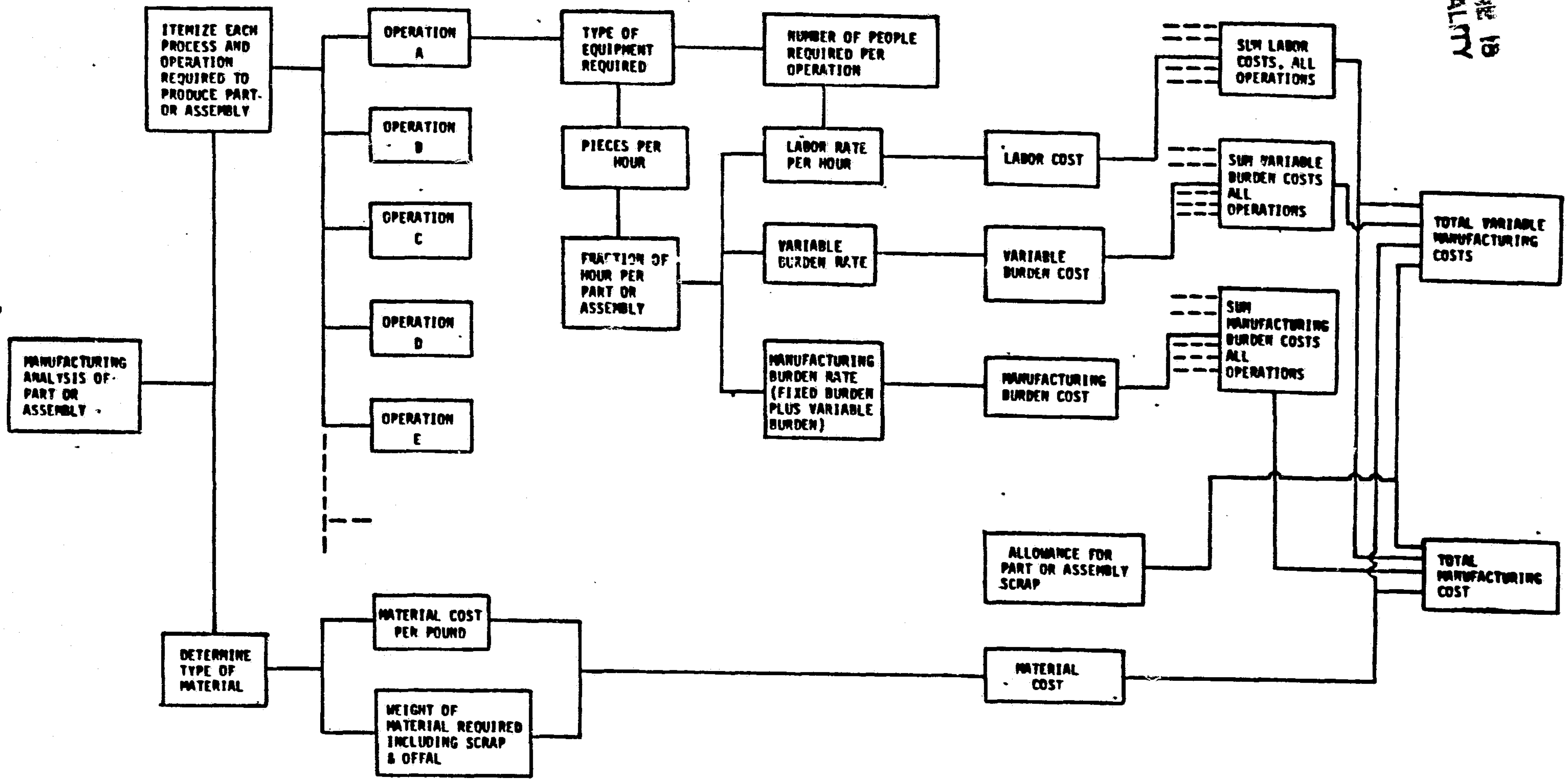


FIGURE 3

"Make" parts, in this case, are primarily weldments and fabricated parts. The cost of these items was obtained by verbal quotations from a mill at mill lot orders.

Prices quoted by volume lot suppliers were used as the basis for the material costs in this study.

A detailed description of "Pioneer's Cost Methodology" is in the Appendix of this report.

PROCESSING CONCEPTS

This receiver, as presently designed, presents the manufacturing engineer with a serious challenge. From the materials - all special high temperature alloys and molded ceramic shapes - to the unique furnace brazing processes, there is little that can be considered conventional in the manufacture of this unit. Therefore, new and inventive special fabrication concepts have had to be devised, and a mixture of old and new techniques and equipment employed.

The following describes the manufacturing processes used, and discusses what is perceived to be several problems inherent in the design of some components.

Core-Heat Exchanger - Segment Assembly (Figure 4) - This is the most complex element of the receiver. It consists of 627 individual parts, fabricated of nickel based materials. All must be fused into a single unit by brazing and welding.

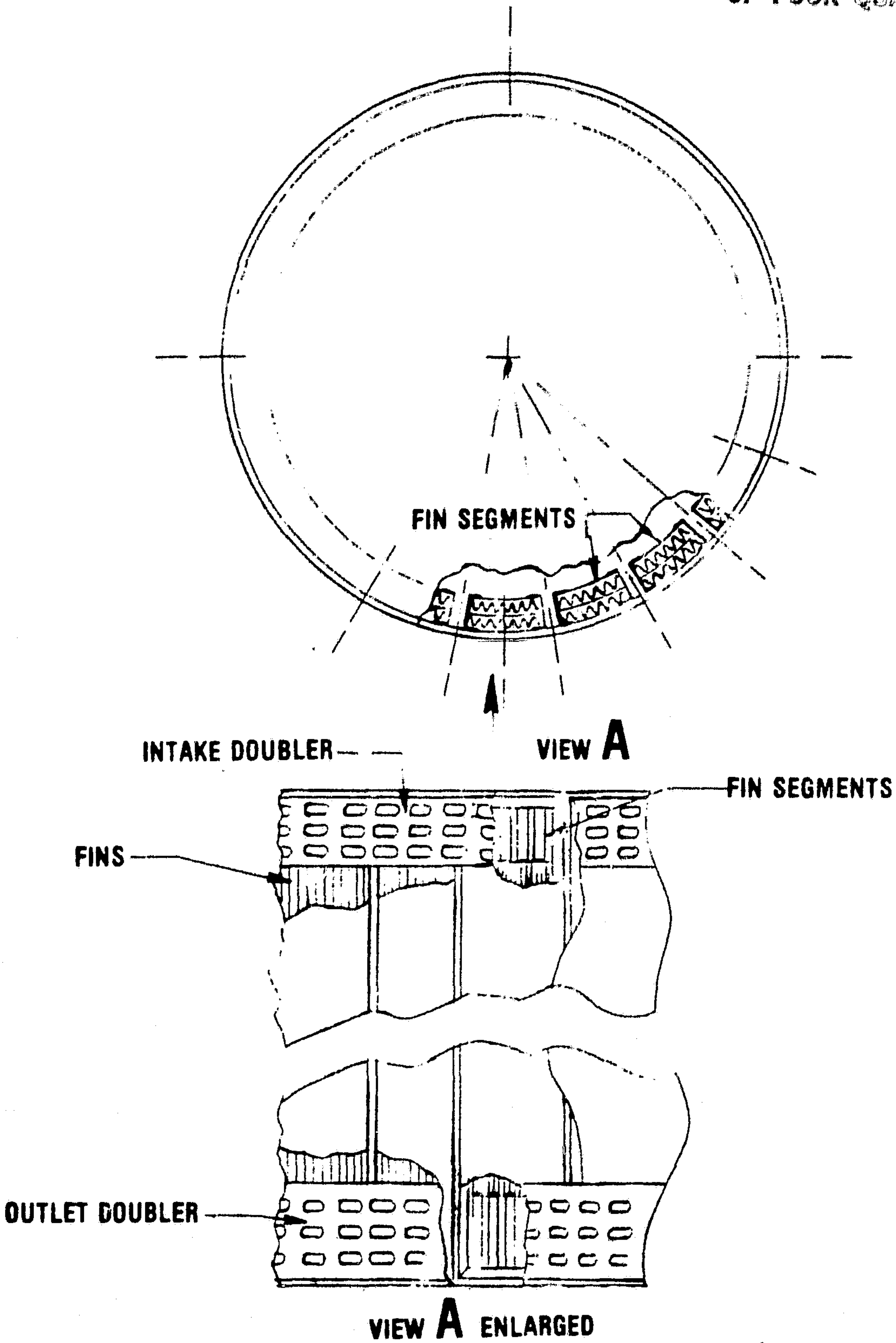
The core is the most critical element of the receiver because of its heat transfer requirements. The heat must transfer from the core interior to the fins, then to the passing air.

For efficient heat transfer, there must be contact between the inner shell segments and the fins. This is accomplished by special fixturing and furnace brazing. To produce a Grade B braze joint (MIL. B-7883-8) between the fins and the inner segment, which is exposed to the sun's rays, these surfaces must be in contact within .002 inches before brazing. The brazing temperature, 2000^{O}F, the delicate nature of the .008 inch thick inner liner, the .002 inch thick fin spacer, and the .005 inch thick fin stock, preclude the use of conventional fixturing methods and materials.

The solution adopted made use of a ceramic box, with lid, for holding the parts. Figure 5 shows such an arrangement for the first subassembly of the core unit.

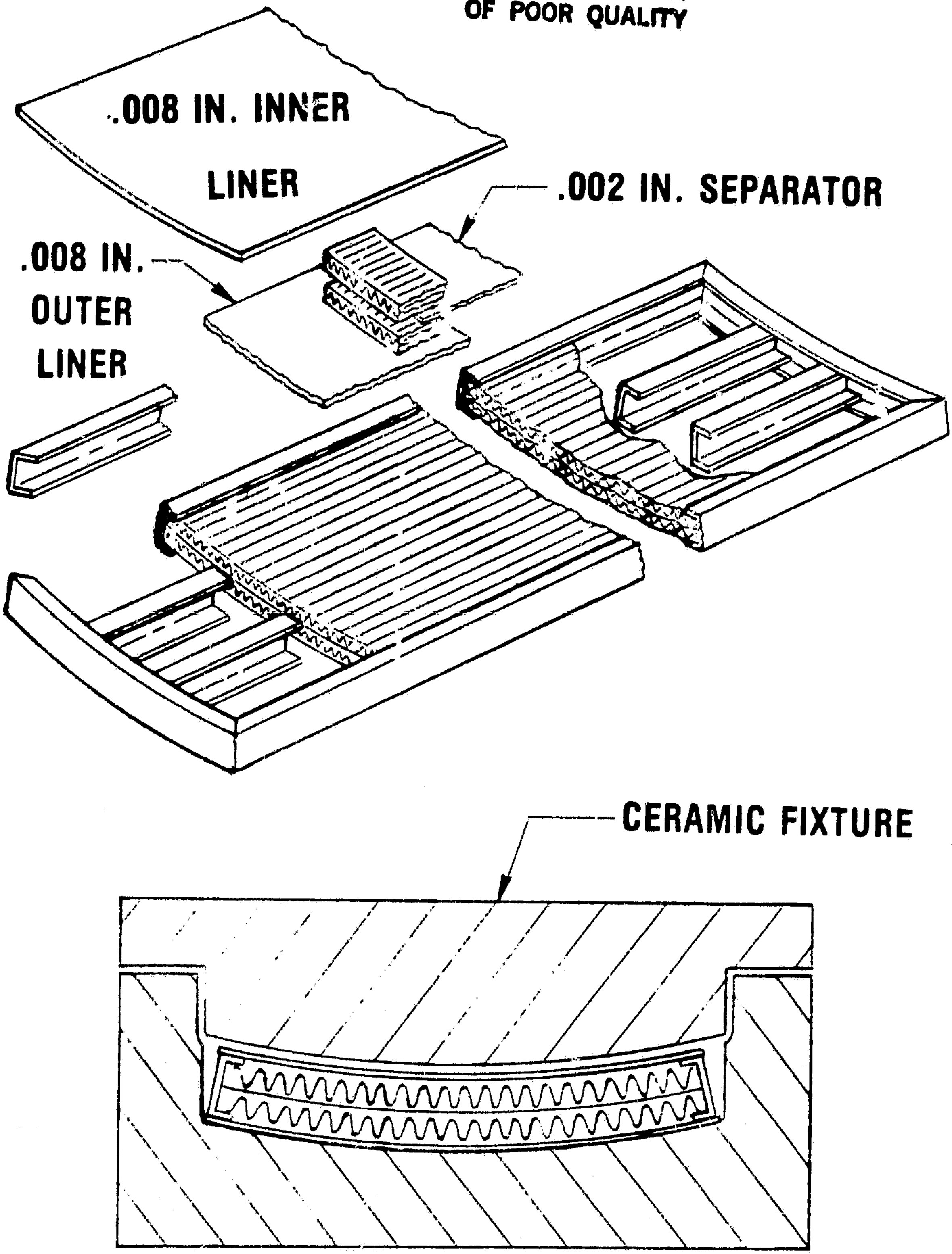
The core is composed of 18 subassemblies, each of which is 3 inches wide by 38 inches long. The subassembly consists of thirty-four separate pieces. The assembly is shown in Figure 5.

Each of the 18 subassemblies must be made to a radius of plus or minus .005 inches to facilitate final assembly to design dimensions. Before loading into the ceramic fixture, some of the parts must be "tack-welded" together, to assure correct alignment. The twelve short channels and inner shell segment is one such group. The long leg of each channel must be joined by brazing to the inner shell segment, an .008 inch thick sheet, 3 inches by 38 inches.



CORE ASSEMBLY

FIGURE 4



CORE SEGMENT ASSEMBLY

FIGURE 5

The four-piece "picture frame" is also welded at the corner joints into a subassembly. These subassemblies, together with the fin sections, are then loaded, convex surface down, into a transverse cylindrical cavity formed in a ceramic block, conforming to the 21 inch diameter of the outer skin. This is shown in Figure 4.

Mating surfaces to be brazed are coated with a liquid brazing compound containing a pulverized Inconel alloy. The specific brazing filler metal is Wall-Colmomoy's "Nicrobraze 35", designed for high temperature use. Being free-flowing, the .002 inch spec, allowed mismatch can be tolerated. No flux is required since a furnace with a controlled atmosphere is used.

Finally, a heavy ceramic cover (refer to Figure 5) is placed over the assembly to force the parts to conform to the desired curvature during the brazing operation. This assembly, because of its long, slender shape, is distortion-prone; the weight of the ceramic cover helps minimize warping.

The ceramic box is then placed in an cven for 3½ hours. Oven temperature reaches a maximum of 2150°F. For production volumes less than 10,000, a batch furnace is used. For higher volumes, a continuous vacuum furnace is used.

The 3½ hour brazing cycle consists of these periods:

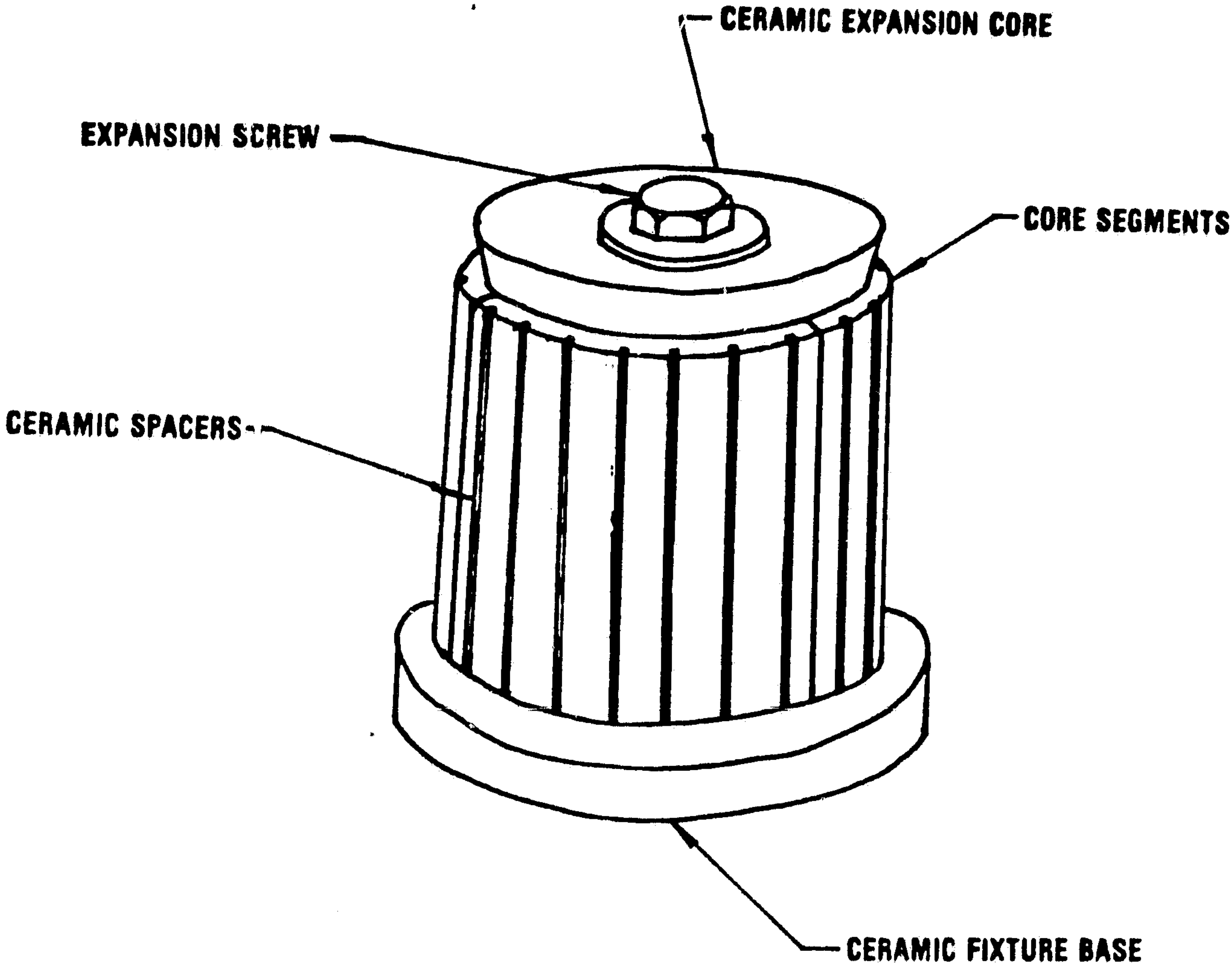
Preheat	10 Minutes
Braze	5 Minutes
Furnace Cool Down	195 Minutes

The 195 minute cool down is required to relieve internal stresses and prevent cracking of the brazed joints.

Since the fin-and-channel subassembly, just discussed, must pass through the brazing furnace a second time during the core assembly, a brazing filler metal was selected that could survive a second heating with no diminution in physical properties.

Core Final Assembly - The remaining 9 parts are jointed with 18 of the fin subassemblies and fused into a single unit by furnace brazing.

Fixturing for this operation is complicated (refer to Figure 6). The parts will be assembled in a vertical position, that is, about a central post or column whose central axis is perpendicular to the floor. The post is ceramic, made up of segments which are radially expandable through action of a tapered, central drawbar.



CORE ASSEMBLY FIXTURE

FIGURE 6

Each fin subassembly is coated with brazing compound. Eighteen of these are arranged about the ceramic post and held against it with spring clamps. The outer shell is then slipped over the fin assemblies. As it is forced downward, the ceramic core segments are expanded slightly so that there is positive contact between fins and shell.

Eight outer elements are assembled next, starting with the outlet-end doubler and two flanges, two locking rings and another doubler with its two flanges. At this point, the center core segments of the fixture post are expanded slightly to lock the outer elements in position.

Brazing compound is applied to the assembly and it proceeds to the brazing ovens. The same oven cycle is used with the fin segments discussed earlier: 3½ hours at 2150°F.

In positioning the 18 fin-and-channel segments about the central ceramic post, a .125 inch spearation between segments must be maintained. Ceramic separators of this thickness are easily damaged and it must be assumed that they must be replaced for each cycle.

Following cool-down, the core is tested for air leaks, and repaired, if required, by hand gas-welding.

Inlet and outlet pans, each fabricated in four-piece segments, are next welded to the core at the flanges; inlet and outlet tubes were previously welded to a pan segment. Welding is by automatic machine, where possible, with a minor amount done by hand. Inert gas, shielded tengsten arc welding is used.

<u>Core Outer Shell</u> - This part is a thin-wall cylinder 21 inches in diameter, 38 inches long. Except for handling, fabrication is relatively straightforward, and it can be made by conventional stamping methods. It starts out as a sheet of .008 inch thick stainless steel, 38" X 65". Following several piercing operations, it is rolled into a cylinder and automatically seam-welded using inert gas shielded tengsten arc welding. The weld joint is planished prior to assembly.

Special handling methods and devices are required in fabricating and storing this .008 inch wall, 20 inch diameter, 38 inch long cylinder.

<u>Material availability could become a major problem</u> in producing high volumes of this receiver. Annual production of Inco 625 by domestic mills is approximately 10,000 tons for all applications. The 100,000 unit annual production this Brayton Receiver

will require 3930 tons. The .002 and .008 sheet stock requires operations by re-roll mills, since the primary mills will not roll so fine a gage. It is anticipated, however, that if sufficient volume were projected, the primary steel mills would invest in the capital equipment to supply this thin sheet in the required volume, limited by the required lead time.

Fin Spacer - This part is .002 inches thick, approximately 2" X 29". Eighteen are required per receiver. Special handling procedure is required because of the length and fine gage. The cost here is based on an arrangement in which the part is automatically fed from a spool, cut off and positioned atop the fin section, where volumes justify.

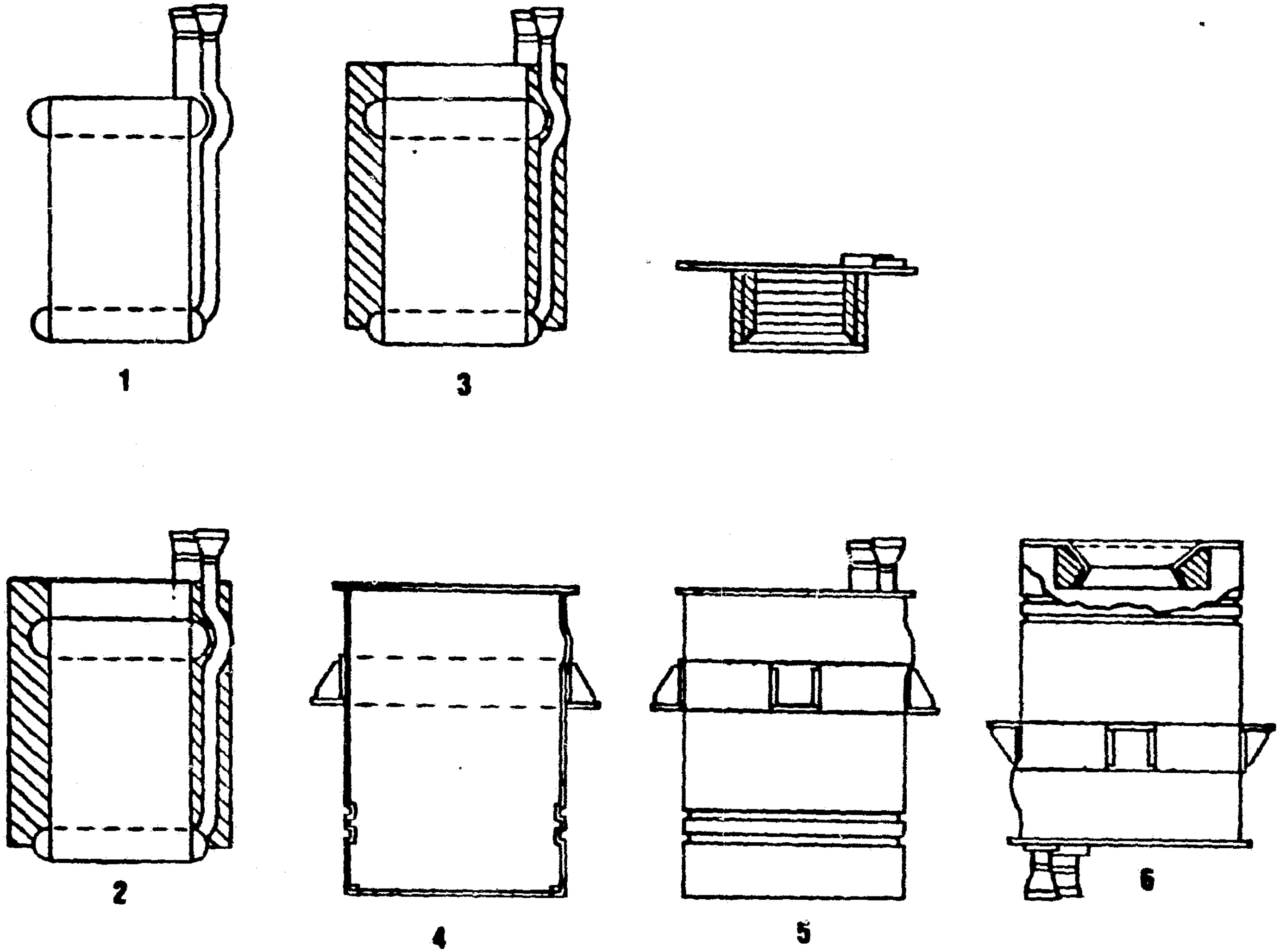
Fins-Heat Transfer - The fins are made of .005 inch thick Inco 625, folded into segments 1/4" X 3½" X 3½". Equipment suppliers advise that, with slight modification, automotive radiator-type rolling and convoluting machines can be used. Production rates would be comparable. 288 of these are required per receiver.

Case Assembly-Outer - This is one of the few receiver components made of carbon steel. It is a thin-wall cylinder, 30 inches in diameter, 45 inches long, .048 inch thick. Heavy-gage end flanges, the mounting ring, and two circular stiffening grooves help to maintain roundness.

The part starts out as a rectangular sheet, is rolled into a cylinder, the longitudinal joint is welded after which the stiffening grooves are rolled. All welds, circular and longitudinal, are automatically welded using inert gas, shielded tengsten arc welding.

Final Assembly - Final assembly methods for the receiver will vary with volume levels. At low volumes, stationary work stations will be used. At higher volumes, some form of moving conveyor, with pallets, is necessary and economical. In either case, a progressive build-up consisting of subassemblies appears to be the most efficient assembly procedure to follow.

The receiver will be assembled in a vertical position with open end down. (Figure 7 depicts the assembly sequence.) Insulation is attached at different stages of sub and final assembly.



FINAL ASSEMBLY SEQUENCE
BRAYTON CYCLE RECEIVER

FIGURE 7

The core, with insulation in place, is next inserted into the case using air-cylinder-equipped fixtures. Concentricity and radial location of case and core are established at this stage. The lock pins are installed to maintain the core-case relationship.

The internal, integrally rolled reinforcement section presents an assembly challenge. A tooling sleeve must be used to prevent the insulation from "hanging-up" and not being properly distributed.

The cover-and-sleeve, insulation and the ceramic reflector plate previously subassembled, is then loaded into the case and core assembly. Ring seals with insulators, are also assembled to the inlet and outlet ducts.

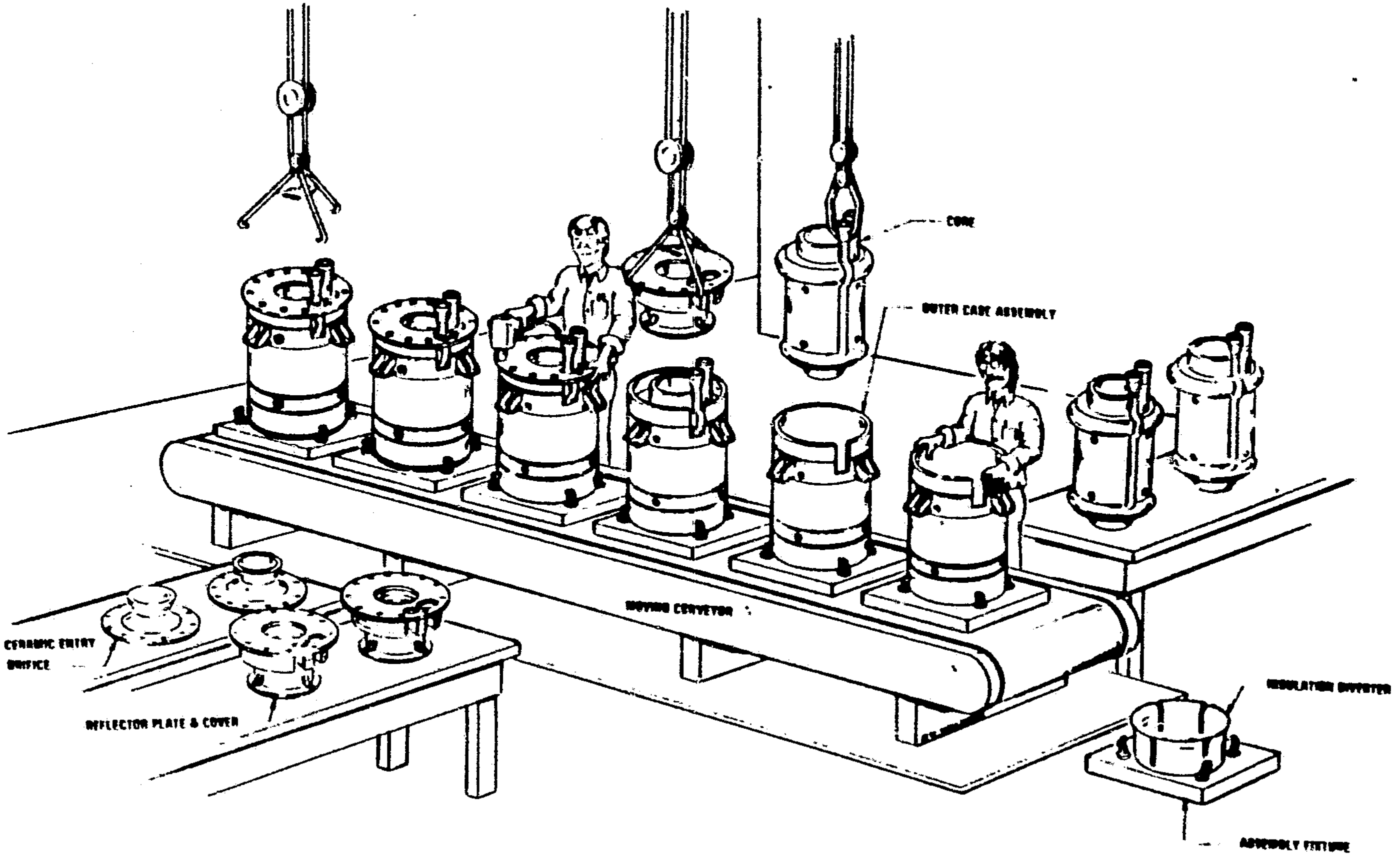
The receiver is then turned over, with open end up. Remaining insulation is packed in. The ceramic orifice is bolted in place. Attachment of the inlet pan cover completes the receiver assembly.

Final assembly operations lend themselves to a limited use of automation. At their present state of development, most parts are awkward to handle, have little structural integrity until assembled, all of which makes manual assembly the preferred approach. The insulation package will need further design development.

Figure 8 illustrates a concept for line assembly of the Air Brayton Cycle Receiver. The subassemblies entering the line are the outer case, the core, the reflector and cover, and the aperture plate. Each of these is put together on a secondary line that feeds into the final assembly. The primary elements of the assembly fixture are the base, locator, and insulation deflector. The locator (not shown) orients the outer case to facilitate orientation with the core to permit assembly of the lock pins. The insulation is precut to permit passage of the lock pin to the mounting ring.

The insulation deflector is designed to permit the insulation to pass over the integrally rolled reinforcements in the outer case. Without this fixture assist, the insulation, preassembled around the core, would hang-up on these internal protrusions, jamming the insulation. As the assembled receiver is removed from the fixture, the deflector is designed to collapse on its way out, permitting the slightly compressed insulation to expand to its design position.

When the core assembly is raised for entry into the outer shell, it is oriented to be aligned with the lock pin entry holes. A device is attached to the loading fixture to blow air between the insulation and the outer case. This is designed to



FINAL ASSEMBLY

BRAYTON RECEIVER

FIGURE 8

create a space that will permit easier assembly of the preinsulated core to the case. As the core is lowered the air device rests on the edge of the case, blowing air into the assembly.

The reflector plate and cover assembly is then manually put into place and bolted into position. The inlet and outlet rings and insulators are installed. The inlet duct by-pass cover is installed. This part does not appear on the design as presented. It was added in costing to accommodate the exposed duct and insulation.

The assembly is then removed from the assembly fixture, inverted, and placed on another line. Here the aperture plate is assembled, the unit is packaged for shipment.

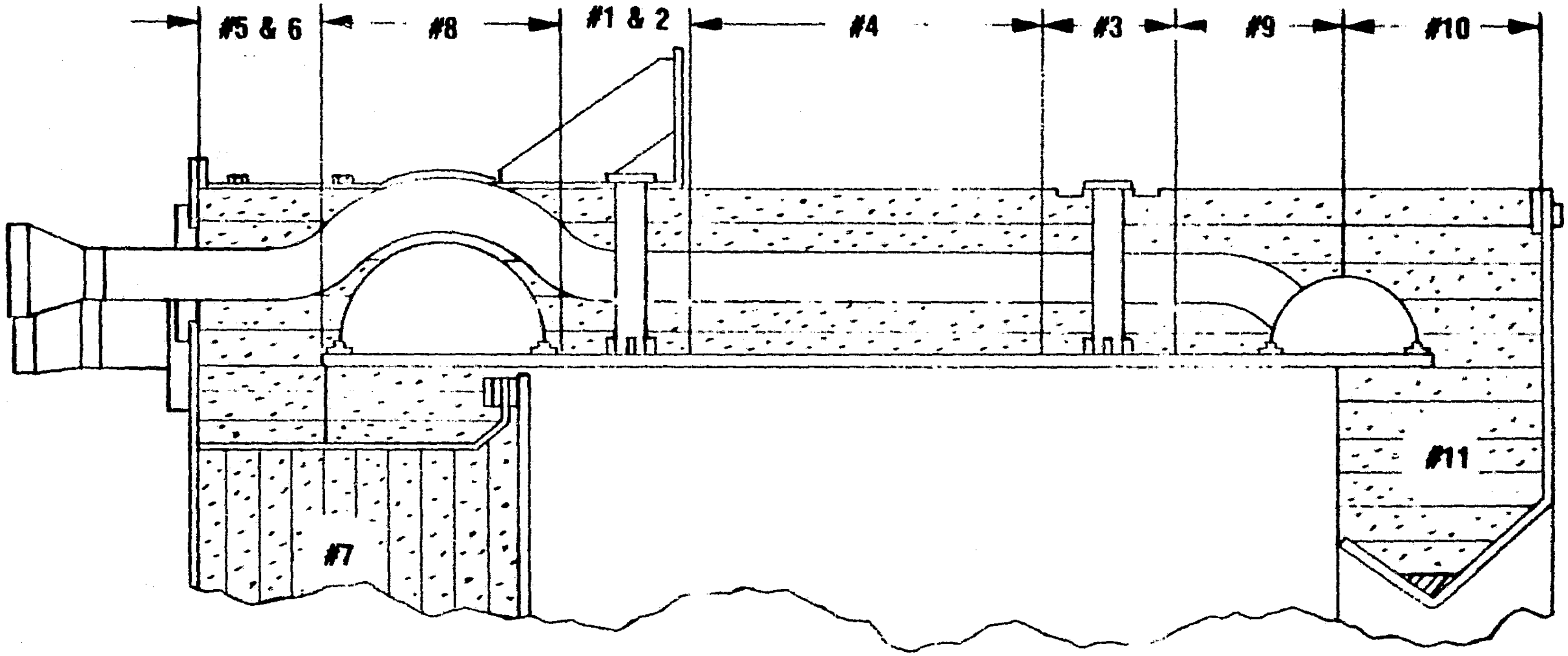
<u>Insulation</u> - Figure 9 shows the manner in which the insulation has been divided to facilitate assembly. The insulation is Cera-Blanket, a Johns-Manville product. It is purchased in rolls and for this application is .75 inches thick. It is slit and cut to length on specially designed, but readily available machines. It is wrapped around the core assembly, the reflector support tube and the aperture plate. Each layer is cut to the proper width and length, each must be hand laid in place.

The Cera-Blanket is handled in about the same way as raw cotton. At 8 pounds per cubic foot it is slightly more dense than raw cotton.

Cera-Blanket lends itself reasonably well to being attached with tape or adhesive. For this reason all of the insulation used for this cost is Cera-Blanket. A review of Figure 9 will show that for this assembly and its irregular contours the insulation was divided into eleven (11) different sections. Each section is made up of layers of 3/4 inch thick Cera-Blanket. Each section requires several pieces of different widths and lengths. There is a total of 113 individual pieces. The total insulation weighs 65.3 pounds, although its density is 8 pounds per cubic foot.

The insulation is applied at various stages of sub and final assembly. Automatic handling, even at high volumes, is difficult and uneconomical. It is a manual operation at any volume.

Handling 113 pieces of insulation at high volumes is cumbersome and costly. A review of the possible use of preformed blocks made of Cera-Foam instead of Cera-Blanket indicates that the most economical insulation for this receiver is the use of Cera-Blanket sheet. The results of this review are shown in Table 1.



INSULATION LAYOUT

FIGURE 9

BRAYTON RECEIVER
INSULATION
COST COMPARISON
CERA-BLANKET vs CERA-FOAM

			FABRICATION		ASSEMBLY		TOTAL
		MATERIAL	LABOR	BURDEN	LABOR	BURDEN	M+L+B
CERA-BLANKET 8# Cu. Ft. 111 Pieces	1MM	111.82	1.73	3.07	9.73	11.82	138.17
	100	180.33	39.38	58.26	13.85	16.82	308.64
CERA-FOAM 12# Cu. Ft. Type 103 44 Pieces (estimated)	1MM	293.85	--	--	2.43	2.96	299.24
	100	440.33	--	--	3.45	4.21	447.99

NOTE: Total Insulation = 65.3# @ 8# per Cu. Ft. or 97.95 Board Feet.

TABLE 1

POTENTIAL COST REDUCTION

It is beyond the scope of this study to question basic design principles. However, as engineers with expertise in product design and manufacturing, Pioneer feels that certain elements of the receiver design could be redesigned for lower cost without affecting basic function.

Presented in this section, are several proposed design changes which can reduce manufacturing cost. Annual cost savings are based on 1,000,000 units per year.

1. GUSSET, Part No. 193106-5 (Figure 10)

This is shown to illustrate the ongoing cost reduction consideration given to all manufacturing operations for all parts. Figure 10 shows the "nesting" of the part in a strip. The configuration is such that the part is best produced two at a time. Without nesting, the added material cost would be $720,000.00 per year at 1,000,000 units. ($.09/pc.; .72/assy.)

2. MOUNTING PAD, Part No. 193106-9 (Figure 11)

A simple contour change, which does not affect function, will permit better material uitlization through closer "blank-nesting". Costing savings would be $200,000.00 per year at 1,000,000 units. ($.20/assy.)

3. RING ASSEMBLY-CORE LOCK, Part No. 193145 (Figure 12)

Present design requires the welding of a four-piece cross in four places on each of two rings. For manufacturing, this was made in two pieces, mating at a notch.

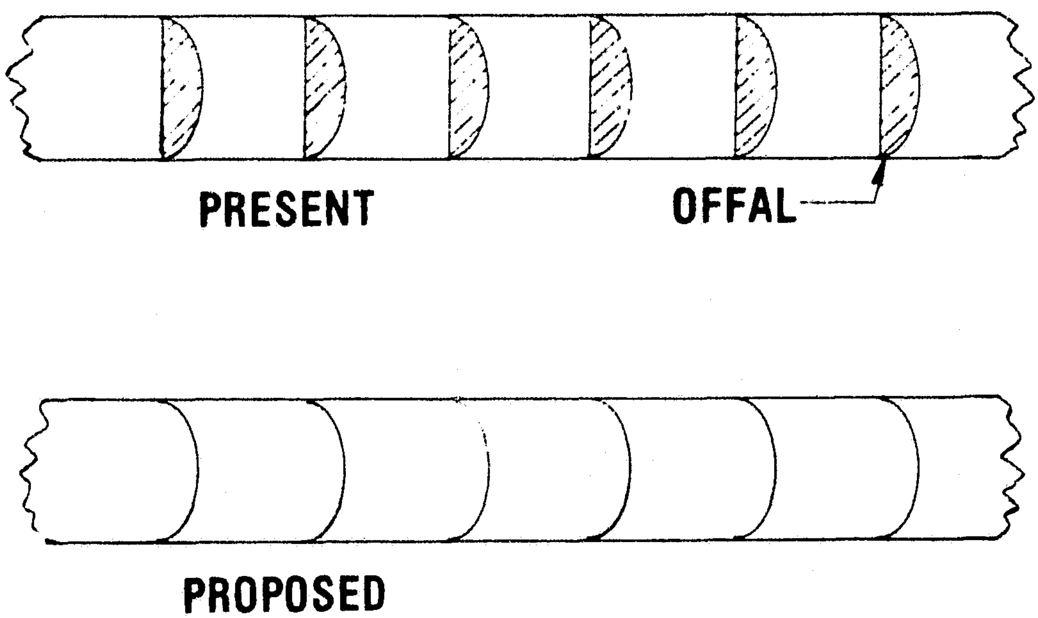
It is proposed that these appended crosses be eliminated and the locating function be accomplished by tabs lanced from the ring material. The tabs can be oriented either axially or radially, if required, to restrict movement in either direction.

Annual savings at 1,000,000 units would be $10,520,000.00. ($10.52/assy.)

ORIGINAL PAGE IS
OF POOR QUALITY

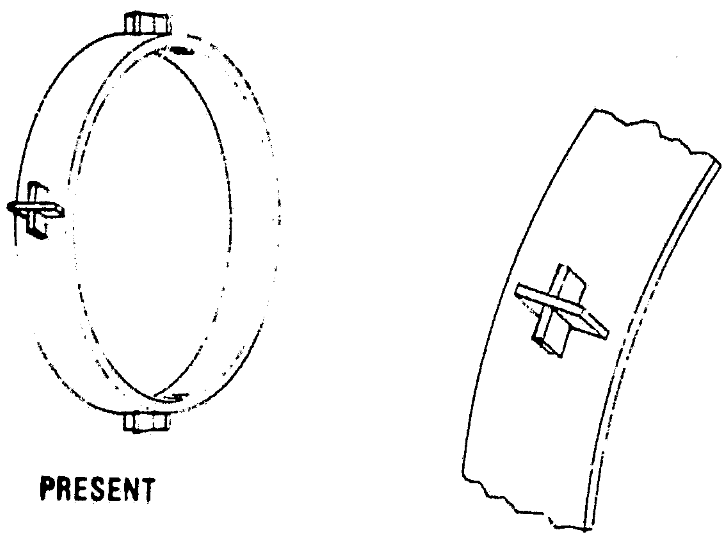
STRIP LAYOUT P.N. 193106-5, GUSSET

FIGURE 10

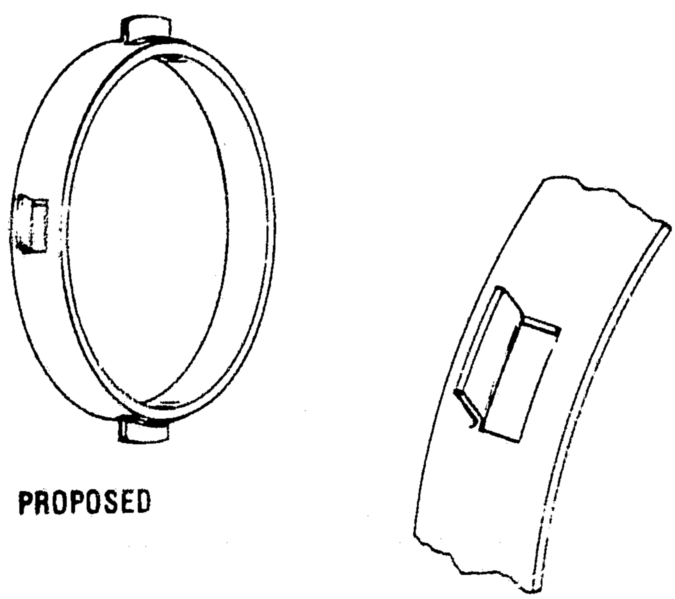


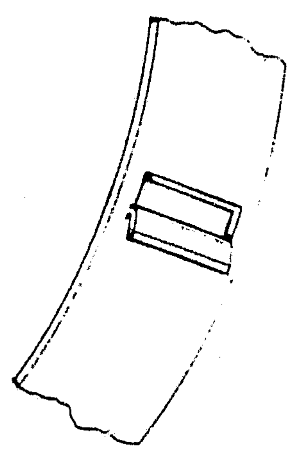
STRIP LAYOUT P.N. 193106-9, MOUNTING PAD

FIGURE 11



PRESENT





PROPOSED

P.N. 113145

RING ASSEMBLY - CORE LOCK

FIGURE 12

4. FLANGE-PAN-OUTLET, INLET, Part No. 193097 (Figure 13)

The current design requires that this 30 inch diameter by ½ inch wide ring be machined on the outside diameter. This machining is costly.

It is proposed to use a ring, rolled to size, eliminating the machining. The pan would be fillet welded to the rings.

Annual savings at 1,000,000 units would be $1,100,000.00. ($1.10/assy.)

5. CASE-OUTER, Part No. 193105 (Figure 14)

The existing design calls for reinforcing grooves produced integrally to the outer case. The depressions provide strength for the lock pins. Being formed inward, they are a serious impediment to the assembly of core and insulation to the outer case. Special tooling was envisioned to overcome the potential "hang-up" of the insulation.

To overcome possible problems it is suggested that these convolutions be rolled outward, rather than inward, as shown in Figure 14. No calculable savings can be offered; but it is reasonably assumed that this change would facilitate assembly.

MATERIAL SUBSTITUTION

Inconel 625, an excellent high temperature alloy, is generously specified in the receiver design. Several areas are listed below where Pioneer feels less expensive temperature resistant material can be used, with a resultant savings.

1. INLET PAN - P.N. 193098-3

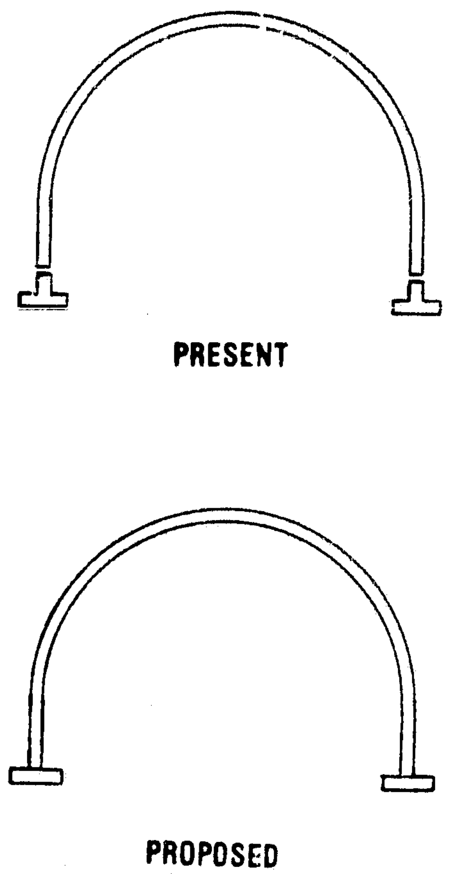
   This is cooled by the cool air entering the system. It could be made from AISI 310.

   Savings at 1,000,000 units would be $10,800,000.00. ($10.80/assy.)

2. INLET TUBE - P.N. 193100-3

   This is cooled by the incoming air. Use AISI 310.

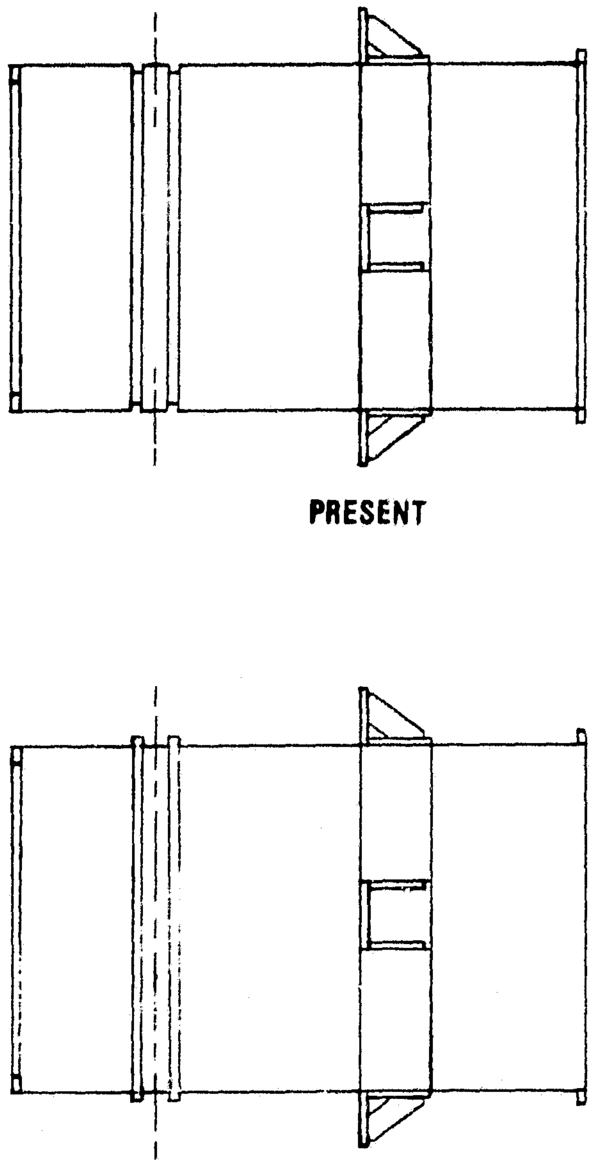
   Savings at 1,000,000 units would be $17,380,000.00. ($17.38/assy.)



PAN & FLANGE ASSEMBLY

FIGURE 13

ORIGINAL PAGE IS
OF POOR QUALITY



PRESENT

PROPOSED

P.N. 193105

CASE - OUTER

FIGURE 14

3. MOUNT ASSEMBLY CORE - P.N. 193128-5 Plate
-7 Tube

Plate is an external part, it should be made of carbon steel.

Savings at 1,000,000 units would be $35,220,000.00 ($35.22/assy.)

Tube is in contact with the lock ring on the core. It may be made of AISI 310.

Savings at 1,000,000 units would be $8,415,000.00. ($8.42/assy.)

COST REDUCTION USING ALTERNATE MATERIALS

The basic Air Brayton Cycle Receiver is a design using a large quantity of Inco 625 in the heat affected areas. This material costs $12.00 per pound as sheet rolled to .060 inch thick. The receiver used sheet as thin as .002 inch. Rerolling to produce this thin section brought the cost to $23.00 per pound.

In an effort to reduce the cost of this receiver, JPL has investigated the use of a less expensive material. Pioneer was asked to determine the degree of cost reduction that might be realized if NDS (Nitride Dispersion Strengthened) 410 were used in place of Inco 625. Also considered was the cost of plasma coating the heat affected areas of the receiver.

As a result of investigating the metallurgical effects of using NDS 410 it was determined that NDS 409 would be a better choice of materials. The costs presented in this report are based on the use of NDS 409.

Nitride dispersion strengthening of steel (Nitriding) is a relatively old and often used method to produce surface hardness. The application of this method to improve the temperature performance of steel, however, has not progressed beyond the laboratory. The reason for this lies in the practical problems encountered in the production of NDS. This report reviews some of the problems. The costing of NDS steels in this report assumes that these steels are producible.

The cost effect of three other material substitutions are also reported herein:

1. Graphite instead of Silicon Carbide in the aperture.
2. RA 330 Steel for Silicon Carbide in the reflector plate.
3. RA 330 Steel for INCo 625 in the reflector plate support sleeve.

RATIONALE FOR SELECTING NDS 409

The original objective of this study element was to replace Inco 625 with NDS 410.

410 Stainless is a hardenable martensitic steel that goes thru a phase change above 1450°F — it hardens when air cooled from that temperature. Martensitic steels are not recommended for service where they will cycle through a phase change.

It was suggested[1] that 409 or 304L would be a better choice for this application. 409, a ferritic stainless, was used for all of the applicable costs in this study. 409 is 03%-40% less costly than 304L.

PROBLEMS IN PRODUCING NDS STEELS

Nitrogen has been used to harden steel for some years. Using a nitriding process for producing high strength, ductile materials is a relatively new concept. To date only laboratory batches of the materials have been produced.

The NDS process requires that titanium be added to the steel melt. This has to be done in a vacuum. This process adds from 150% to 300% to the cost of producing the base material, depending on the amount of titanium and the alloy system used.[2]

The current practical limit for the thickness of NDS sheet is .010 inch. Thicker gages affect the metallurgical characteristics and therefore the strength. The practical limit to the width of a sheet today is 12 inches; the preferred maximum width is 6 inches. This results from the need to maintain close control on the temperature across the sheet, inasmuch as a variance in the temperature results in metallurgical differences.[3]

One of the parts in this study is 38 inches wide; current technology can only produce 12 inch sheets. For the sake of this study it was assumed that 38 inch sheets will be produced.

Heating of the sheet during nitriding must be done with quartz lamps rather than conventional furnaces. The nascent nitrogen of the process has an affinity for anything that is at the temperature required for nitriding, even the furnace walls. In a conventional furnace these walls would become brittle and subject to breaking.

After being exposed to the nitrogen atmosphere the material is too brittle to be worked and formed. The excess nitrogen must be removed to render the base material ductile. This requires a two hour furnace treatment at 2000°F with a controlled atmosphere to remove the nitrogen.

[1] Mr. Aggren, Allegheny-Ludlum Steel Co.

[2] "Development of Nitride Dispersion Strengthened (NDS) Alloys for Application to Advanced Heat Exchangers", Jim O'Reilly, AiResearch Division, Garrett Corp., Report No. 79-16367, P. 5.

[3] IBID, P. 3.

To obtain a piece of material greater than .010 inch thick it is necessary to use stacks of .010 inch sheet. This stack must be pressure bonded in a vacuum. The stack is encased in a metal box that is evacuated and welded. The entire assembly is hot roll bonded, and the outer cover is removed by pickling in dilute nitric acid.[4] As many as 150 sheets may be bonded into one piece.

An alternation method for building thick sections is the use of powdered metal. This process is more expensive than pack rolling foil.[5]

ALTERNATE MATERIALS FOR COST REDUCTION

1. 409 Stainless Steel - This was used for this study instead of 410. 410 is an air hardenable martensitic steel and was not recommended for this application. 409 is ferritic, more suitable for the cyclic temperature changes, and it is 18 to 20% less costly than 410.

2. 304L Stainless Steel - This is an austenitic stainless that will also withstand the cyclic temperature changes better than 410. It is, however, 30%-40% higher in cost than 409.

3. RA 330 - This material has been used in this study as a replacement for the ceramic reflector plate. It costs 3 to 3½ times as much as 409, but does not require N.D.S. There is a verbal consensus that it will perform well in this application. A thorough metallurgical and heat exchange analysis is needed to verify the hypothesis. RA 330 is presently being used for the walls of furnaces that operate at 2400-2500°F.

4. A more radical, but not to be overlooked alternative, is the use of a high strength carbon alloy steel with an aluminum plasma coat at the heated area. (Len Brumbaugh, Metallizing of America) The theory is that the steel surface, sprayed with AL and heated to 2000°F for two hours, will have a protective coat of AL_20_3, which melts at 3600°F. Used in hot rod exhaust stacks, this treatment outlast stainless steel by as much as 300%.

[4]IBID, P. A-10.
[5]IBID, P. 5.

PLASMA COATING

In an effort to increase the effective use of alternate materials (409), consideration was given to plasma coating the receiver components. As mentioned above an aluminum coating is an excellent thermal barrier. However, plasma coating generally contributes nothing to the strength of the substrate.

The corrosion protection afforded by plasma coatings is marginal, unless the coating is fused by post heating. The basic application of a plasma coat is 85% to 98% of theorectical density, depending upon the material and particle size.[6] This leaves a porous surface thru which the substrate may be attached. Heating coated parts to the correct temperature will cause the particles of the plasma coat to fuse and form a solid surface, impenetrable to corrosion.

This fusing temperature is high ($> 2000^{o}$F) and can damage the part being coated. In the Brayton Receiver the sections are such that the assembled system could warp if subjected to the required fusing temperatures. Plasma coating cannot be depended upon to provide a corrosion resistant coating.

The configuration of the Brayton Receiver is such as to limit the application of plasma coating to the inner skin where the insolation is concentrated. This is the only heat affected area that is accessible after assembly. It is possible to spray other heat affected elements before assembling the core to the outer case, but there is serious question as to the value of such coating, aside from overcoming the practical problems.

The core is a brazed assembly. The elements cannot be sprayed prior to brazing. Coating after brazing would coat the fins, affecting the heat transfer characteristics. Aside from heat transfer, the fins, .002 inches thick, would be affected physically.

It was Pioneer's judgement that only the inside shell could be advantageously plasma coated. The costs shown in this report are based on that premise.

NDS - FINISHED ASSEMBLIES

The problems associated with NDS steel are briefly catalogued earlier in this report. Some comments have been made regarding the possibility of nitrogen dispersion strengthening a completed assembly such as the Brayton cycle receiver.

[6] "Guide to Use of Plasma Coatings", T. G. Figlioli, P & W Aircraft, P. 3.

Inasmuch as NDS is accomplished by exposing a part to nitrogen gas at a given temperature, any part can be so treated. Since only the core is exposed to the elevated temperatures, it would be logical that only the core elements should be exposed to NDS. Theoretically the finned core assemblies can go thru the NDS and the subsequent de-nitriding treatment to render them resilient. These segments could then be made into the final receiver assembly.

The consensus among those who are aware of the state of the art to date, however, indicates that when an assembly is exposed to NDS, the required temperature will cause the assembly to warp. The warping will/may occur during both the nitriding and de-nitriding cycles. The degree of warping is speculative — it can only be determined experimentally.

RESULTS

I - BASIC AIR BRAYTON CYCLE RECEIVER — AS DESIGNED

This study developed Manufacturing Cost numbers for the Air Brayton Cycle Receiver in annual production quantities of 100; 1,000; 5,000; 10,000; 50,000; 100,000 and 1,000,000 units.

All costs are expressed in 1980 dollars.

Table 2 presents the complete cost of the Air Brayton Receiver for the annual production quantities evaluated. The cost of capital equipment is included in the manufacturing burden, however, the cost of tooling is not. Table 3 shows the production infrastructure required.

The cost (labor, material, burden) of the receiver varies from a low of $2,472.68 to a high of $4,821.43, depending on the annual production volume.

Tooling costs range from a high of $27,376,000 to a low of $488,000.

Machinery and equipment costs vary from a high of $162,672,000 to a low of $217,000.

The direct labor personnel required varies from a low of 2 to a high of 1342, depending on the annual production volume.

Table 4 illustrates the potential cost savings if the proposed design changes were implemented.

If all of the illustrated design changes were implemented, a saving of approximately 3.4% could be realized on the cost of the assembly at the 1,000,000 volume.

Implementing a comprehensive value engineering analysis could result in a cost reduction of up to 15%.

II - COST REDUCTION USING ALTERNATE MATERIAL

Table 5 summarizes the net effect of the potential material changes on the Brayton Cycle Receiver.

Table 6 lists the savings realized in using AISI 409 in place of certain applications of Inco 625.

BRAYTON CYCLE SOLAR RECEIVER
TOTAL MANUFACTURING COST PER UNIT FOR
SELECTED ANNUAL PRODUCTION VOLUMES

ANNUAL VOLUME	WGT/ASSY	MATERIAL $	LABOR MINUTES	LABOR $	BURDEN $	M+L+B $	TOOLING -000-	MACH. & EQUIP. -000-
1,000,000	415.15	2328.46	161.06	28.04	116.18	2472.68	27,376	162,672
100,000	415.15	2371.81	197.38	34.26	128.30	2534.37	5,596	18,415
50,000	415.15	2372.78	263.95	45.76	151.44	2569.98	3,123	9,799
10,000	415.15	2527.60	671.32	117.01	329.95	2974.56	1,226	3,145
5,000	415.15	2575.67	711.28	124.03	345.31	3045.01	1.071	1,820
1,000	415.15	2766.07	1386.23	232.70	693.26	3692.03	795	944
100	415.15	3414.63	1787.93	316.36	1090.44	4821.43	488	217

TABLE 2

BRAYTON CYCLE SOLAR RECEIVER
INFRASTRUCTURE
FOR
VARIOUS ANNUAL VOLUMES

	MINUTES/ ASSEMBLY	DIRECT LABOR PERSONNEL	FLOOR AREA* -000- SQ. FT.	CONSTRUCTION COST -000-
1,000,000	161.06	1342	302	24,160
100,000	197.38	165	38	3,040
50,000	263.95	110	25	2,000
10,000	671.32	56	13	1,040
5,000	711.28	30	10	800
1,000	1386.23	12	10	800
100	1787.93	2	4	320

*Two Shifts - 4000 hours Per Year Assumed.

TABLE 3

BRAYTON CYCLE RECEIVER
POTENTIAL SAVINGS
MATERIAL AND DESIGN CHANGES

PART	P.N.	TYPE OF CHANGE	SAVINGS PER ASSY. $
MOUNTING PAD	193106-9	DESIGN	.20
RING-CORE LOCK	193145	DESIGN	10.52
FLGE-PAN	193097	DESIGN	1.10
INLET PAN	193098	MATERIAL	10.80
TUBE-INLET	193100	MATERIAL	17.38
MOUNT-CORE	193128-5	MATERIAL	43.64
TOTAL			83.64

% Savings At 1,000,000 Volume = 3.4% per Assy.

NOTE: These savings represent a cursory cost reduction analysis performed as a function of cost reduction.
A thorough cost reduction analysis (Value Engineering) has the potential of reducing the cost by as much as 15%.
This judgement is based on the savings experienced in the application of value engineering principles.

TABLE 4

SUMMARY
NET EFFECT OF MATERIAL CHANGES
BRAYTON CYCLE RECEIVER

	100	1,000	5,000	10,000	50,000	100,000	100,000,000
COST OF ASSEMBLY AS DESIGNED	4821	3692	3045	2975	2567	2534	2473
SAVINGS/NDS 409	427	456	526	543	544	545	548
SAVINGS/PENALTY WITH GRAPHITE & RA330	326	306	301	299	293	287	261
NEW ASSEMBLY COST	4068	2930	2218	2133	1730	1702	1664

TABLE 5

SUMMARY
COST OF USING NDS 409 IN PLACE OF INCO 625
BRAYTON CYCLE RECEIVER

	100***	1,000***	5,000***	10,000	50,000	100,000	1,000,000
1. WEIGHT OF PARTS (LBS)	90	90	90	90	90	90	90
2. ORIGINAL MATERIAL COST	1229	1228	1228	1219	1220	1220	1221
3. NEW MATERIAL COST*	202	193	166	156	156	156	155
4. COST SAVING	1027	1035	1062	1063	1064	1064	1066
5. NITRIDE STEEL PREP**	303	290	249	234	234	234	233
6. COST TO NITRIDE & DENITIRDE**	157	157	157	157	157	157	157
7. PLASMA COAT**	40	32	30	29	29	28	28
8. HOT ROLL BONDING**	100	100	100	100	100	100	100
TOTAL NDS COST (3+5 thru 8)	802	772	702	676	676	675	673
NET SAVING	427	456	526	543	544	545	548

*This is base material only; does not include NDS.

**See Page 42 for cost explanations.

***Figures shown for this volume are tentative. It is doubtful that anyone would produce NDS steel in so low a volume.

TABLE 6

TABLE 6

SPECIAL PROCESS COST DERIVATION

5.** NITRIDE STEEL PREP

This cost reflects a steel mill alloying process necessary to introduce sufficient titanium to the base material (409) to combine with and retain nitrogen in dispersion strengthening, it also includes annealing and grinding at various stages in rolling the material to the required thickness. The cost extra is assumed to be 150% of the base material cost.

6.** NITRIDE & DENITRIDE

These costs are based on the assumed existence of a vendor (heat treat specialist) with the necessary equipment and expertise to NDS enough material to satisfy the volume required. Mr. Neal McDonald, metallurgist for Commercial Steel Treating, felt that the cost would be between $1.50 and $2.00 per pound, we used $1.75.

7.** PLASMA COAT

This includes sand blasting, cleaning and plasma spraying the I.D. of the heat exchanger. The material used was aluminum oxide and cost $1.55 to $1.85 per pound depending on volume. Most other materials available for plasma coating are more costly, nickel aluminide a possible choice, would add approximately $15.00 per unit. These costs do not include a fusing operation after spraying.

8.** HOT ROLL BONDING

This is a process necessary because of the material thickness limitation of NDS. Parts thicker than .010 inches must be made by stacking and hot rolling (in a vacuum) to the desired thickness. This procedure has, so far, only been accomplished under laboratory conditions. The cost presented here is a minimum cost and assumes available expertise, equipment and process necessary to meet volumes required.

Table 7 lists the savings/penalty in replacing SiC elements with graphite and RTA 330, as well as one 625 substitution with RA 330.

Tables 8 - 14 list the cost of each Inco 625 detail, in each volume, as it is substituted with AISI 409.

SUMMARY
COST OF REPLACING CERAMIC PARTS
BRAYTON CYCLE RECEIVER

	100	1,000	5,000	10,000	50,000	100,000	1,000,000
APERTURE PLATE							
Si C - Old Cost	495	440	417	407	399	396	380
Graphite - New Cost	500	450	425	407	400	400	390
- Penalty	(5)	(10)	(8)	(0)	(1)	(4)	(10)
REFLECTOR PLATE							
Si C - Old Cost	385	341	317	308	298	295	275
RA330 - New Cost	95	74	61	61	57	57	57
- Savings	290	267	256	247	241	238	218
SUPPORT SLEEVE							
625 - Old Cost	80	80	79	77	77	77	77
RA330 - New Cost	39	31	26	25	24	24	24
- Savings	41	49	53	52	53	53	53
NET SAVINGS	326	306	301	299	293	287	261

TABLE 7

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 100

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	7.12	45.03
DOUBLER	090-5	.407	1	.407	6.60	.91	5.69
DOUBLER	090-7	.231	1	.231	3.80	.52	3.28
SHELL - OUTER	091-1	6.060	1	6.060	77.64	17.68	59.96
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	14.00	61.96
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	11.09	61.63
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.27	1.33	6.94
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	49.75	9.50	40.25
DOUBLER - INLET PAN	096-1	2.590	1	2.590	33.57	6.78	26.79
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	25.09	140.51
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	51.00	7.46	43.54
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.600	68.38	9.96	58.42
TUBE - OUTLET END	099-7	.416	2	.832	10.09	1.49	8.60
STIFFENER	099-9	.330	2	.660	7.92	1.16	6.76
CHANNEL - INLET END	102-1	.028	108	3.024	37.12	5.62	31.50
CHANNEL - OUTLET END	102-2	.0296	108	3.197	38.79	5.83	32.96
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 8

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 100

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338	NO CHANGE		
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710	NO CHANGE		
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690	NO CHANGE		
MOUNT ASSY. CORE	128-5	.185	3	.555	6.77	1.04	5.73
MOUNT ASSY. CORE	128-7	.233	1	.233	4.16	1.97	2.19
MOUNT ASSY. CORE	128-9	.180	1	.180	3.22	1.52	1.70
MOUNT ASSY. CORE	128-11	.191	1	.191	3.41	1.61	1.80
RING - CORE LOCK	145-3	2.000	2	4.000	48.52	6.50	42.02
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.91	.47	2.44
SPACER	292-1	.036	18	.648	10.53	6.48	4.05
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.13	39.67
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	5.96	50.47
TOTAL					1228.63	201.82	1026.81

TABLE 8 (Con't)

SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 1,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	6.37	45.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.74	.46	3.28
SHELL - OUTER	091-1	6.060	1	6.060	77.61	17.48	60.13
SHELL - SEG. INNER	092-1	.349	18	6.282	76.00	12.40	63.60
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	11.09	61.63
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.27	1.33	6.96
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	49.72	9.50	40.22
DOUBLER - INLET PAN	096-1	2.590	1	2.590	33.57	6.78	26.79
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	17.98	147.62
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.00	7.46	42.54
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.600	68.40	9.96	58.44
TUBE - OUTLET END	099-7	.416	2	.832	10.10	1.48	8.62
STIFFNER	099-9	.330	2	.660	7.92	1.16	6.76
CHANNEL - INLET END	102-1	.028	108	3.024	37.12	5.62	31.50
CHANNEL - OUTLET END	102-2	.0296	108	3.197	38.79	5.83	32.96
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 9

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 1,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		N O CHANGE	
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710		N O CHANGE	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		N O CHANGE	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.78	1.04	5.74
MOUNT ASSY. CORE	128-7	.233	1	.233	4.18	1.48	2.70
MOUNT ASSY. CORE	128-9	.180	1	.180	3.23	1.14	2.09
MOUNT ASSY. CORE	128-11	.191	1	.191	3.43	1.21	2.22
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	6.50	41.98
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.91	.47	2.44
SPACER	292-1	.036	18	.648	10.33	4.12	6.41
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.13	39.67
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	10.35	46.08
TOTAL					1227.38	192.74	1034.86

TABLE 9 (Con't)

SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 5,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	6.37	46.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.73	.46	3.27
SHELL - OUTER	091-1	6.060	1	6.060	77.62	16.14	61.48
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	12.40	63.56
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	7.20	65.52
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.27	1.33	6.94
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	49.72	6.53	43.19
DOUBLER - INLET PAN	096-1	2.590	1	2.590	33.57	5.05	28.52
FLANGE - IN-OUTLET PAN	097 A	1.752	8	13.800	165.60	17.98	147.62
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.92	4.66	45.26
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.400	68.28	6.22	62.06
TUBE - OUTLET END	099-7	.416	2	.832	10.08	.92	9.16
STIFFENER	099-9	.330	2	.660	7.92	.70	7.22
CHANNEL - INLET END	102-1	.028	108	3.024	37.09	3.89	33.20
CHANNEL - OUTLET END	102-2	.0296	108	3.197	38.77	4.10	34.67
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 10

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 5,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		NO CHANGE	
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710		NO CHANGE	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		NO CHANGE	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.78	1.04	5.74
MOUNT ASSY. CORE	128-7	.233	1	.233	4.16	1.48	2.68
MOUNT ASSY. CORE	128-9	.180	1	.180	3.23	1.14	2.07
MOUNT ASSY. CORE	128-11	.191	1	.191	3.43	1.21	2.22
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	4.24	44.24
GUSSET - GORE LOCK	145-5,7	.030	8	.240	2.91	.26	2.65
SPACER	292-1	.036	18	.648	10.48	3.92	6.56
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.12	39.68
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	7.52	48.91
TOTAL					1228.20	166.28	1061.90

TABLE 10 (Con't)

SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 10,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.225	1	3.227	52.15	6.37	45.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.73	.46	3.27
SHELL - OUTER	091-1	6.060	1	6.060	73.42	11.96	61.46
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	12.40	63.56
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	7.20	65.52
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.27	.79	7.48
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	47.55	4.36	43.19
DOUBLER - INLET PAN	096-1	2.590	1	2.590	31.40	2.88	28.52
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	18.00	147.60
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.92	4.68	46.24
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.600	68.28	6.24	62.04
TUBE - OUTLET END	099-7	.416	2	.832	10.08	.92	9.16
STIFFENER	099-9	.330	2	.660	7.92	.71	7.21
CHANNEL - INLET END	102-1	.028	108	3.024	36.72	3.89	32.83
CHANNEL - OUTLET END	102-2	.0296	108	3.197	38.77	4.10	34.67
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 11

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 10,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		NO CHANGE	
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710		NO CHANGE	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		NO CHANGE	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.72	.60	6.12
MOUNT ASSY. CORE	128-7	.233	1	.233	3.78	1.03	2.75
MOUNT ASSY. CORE	128-9	.180	1	.180	3.23	.80	2.43
MOUNT ASSY. CORE	128-11	.191	1	.191	3.42	.84	2.58
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	4.24	44.24
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.88	.26	2.62
SPACER	292-1	.036	18	.648	10.48	3.91	6.57
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.13	39.67
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	7.52	48.91
TOTAL					1218.81	155.69	1063.12

TABLE 11 (Con't)

SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 50,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	6.37	45.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.73	.46	3.27
SHELL - OUTER	091-1	6.060	1	6.060	73.42	11.96	61.46
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	12.40	63.56
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	7.20	65.52
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.28	.79	7.49
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	47.55	4.36	43.19
DOUBLER - INLET PAN	096-1	2.590	1	2.590	31.40	2.88	28.52
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	18.00	147.60
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.92	4.68	46.24
PAN ASSY - OUTLET	099 P,Q	1.400	4	5,600	68.28	6.24	62.04
TUBE - OUTLET END	099-7	.416	2	.832	10.09	.92	9.17
STIFFENER	099-9	.330	2	.660	7.92	.71	7.21
CHANNEL - INLET END	102-1	.028	108	3.024	37.05	3.89	33.16
CHANNEL - OUTLET END	102-2	.0296	108	3.197	39.14	4.10	35.04
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 12

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 50,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		N O C H A N G E	
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710		N O C H A N G E	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		N O C H A N G E	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.72	.60	6.12
MOUNT ASSY. CORE	128-7	.233	1	.233	4.17	1.04	3.13
MOUNT ASSY. CORE	128-9	.180	1	.180	3.22	.80	2.42
MOUNT ASSY. CORE	128-11	.191	1	.191	3.42	.85	2.57
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	4.24	44.24
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.94	.26	2.68
SPACER	292-1	.036	18	.648	10.48	3.91	6.57
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.13	39.67
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	7.52	48.91
TOTAL					1219.97	155.71	1064.26

TABLE 12 (Con't) SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 100,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	6.37	45.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.73	.46	3.27
SHELL - OUTER	091-1	6.060	1	6.060	73.42	11.96	61.46
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	12.40	63.56
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	7.20	65.52
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.27	.79	7.48
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	47.55	4.36	43.19
DOUBLER - INLET PAN	096-1	2.590	1	2.590	31.40	2.88	28.52
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	18.00	147.60
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.88	4.68	46.20
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.600	68.28	6.24	62.04
TUBE - OUTLET END	099-7	.416	2	.832	10.09	.92	9.17
STIFFENER	099-9	.330	2	.660	7.92	.71	7.21
CHANNEL - INLET END	102-1	.028	108	3.024	37.42	3.89	33.53
CHANNEL - OUTLET END	102-2	.0296	108	3.197	39.12	4.10	35.02
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 13

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 100,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		NO CHANGE	
SLEEVE - REFLECT SUPT.	118-1	5.710	1	5.710		NO CHANGE	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		NO CHANGE	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.72	.60	6.12
MOUNT ASSY. CORE	128-7	.233	1	.233	4.17	1.03	3.14
MOUNT ASSY. CORE	128-9	.180	1	.180	3.22	.80	2.42
MOUNT ASSY. CORE	128-11	.191	1	.191	3.42	.84	2.58
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	4.24	44.24
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.91	.26	2.65
SPACER	292-1	.036	18	.648	10.48	3.91	6.57
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	286.52	43.60	242.92
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.13	39.67
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	7.52	48.91
TOTAL					1220.24	155.69	1064.55

TABLE 13 (Con't)

SHEET 2 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 1,000,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DOUBLER	090-3	3.227	1	3.227	52.15	6.37	45.78
DOUBLER	090-5	.407	1	.407	6.58	.80	5.78
DOUBLER	090-7	.231	1	.231	3.73	.46	3.27
SHELL - OUTER	091-1	6.060	1	6.060	73.42	11.96	61.46
SHELL - SEG. INNER	092-1	.349	18	6.282	75.96	12.42	63.54
CHANNEL - HEAT EX.	093-1	.167	36	6.012	72.72	7.20	65.52
CAP - CHANNEL - HEAT EX.	094-1	.019	36	.684	8.28	.72	7.56
DOUBLER - OUTLET PAN	095-1	3.922	1	3.922	47.55	4.35	43.20
DOUBLER - INLET PAN	096-1	2.590	1	2.590	31.40	2.88	28.52
FLANGE - IN-OUTLET PAN	097 A	1.725	8	13.800	165.60	18.00	147.60
PAN ASSY - INLET	098 P,Q	1.050	4	4.200	50.92	4.68	46.24
PAN ASSY - OUTLET	099 P,Q	1.400	4	5.600	68.28	6.24	62.04
TUBE - OUTLET END	099-7	.416	2	.832	10.08	.96	9.12
STIFFENER	099-9	.330	2	.660	7.92	.70	7.22
CHANNEL - INLET END	102-1	.028	108	3.024	37.80	3.88	33.92
CHANNEL - OUTLET END	102-1	.0296	108	3.197	38.88	4.10	34.78
DUCT - TRANSIT. OUTLET	103-1	.169	2	.338		N O C H A N G E	

TABLE 14

SHEET 1 of 2

BRAYTON CYCLE RECEIVER
MATERIAL SUBSTITUTION COST EFFECT
AISI 409 FOR INCO 625

VOLUME 1,000,000

DESCRIPTION	PART NO. 193-	WT/PC LBS	PCS/ ASSY.	WT/ ASSY. 105	ORIG.MATL 625 COST/ASSY $	NEW MATL 409 COST/ASSY $	COST/ASSY.
DUCT - TRANSIT. INLET	104-1	.169	2	.338		N O C H A N G E	
SLEEVE - REFLECT. SUPT.	118-1	5.710	1	5.710		N O C H A N G E	
CLIP - REFLECTOR SUPT.	119-1	.230	3	.690		N O C H A N G E	
MOUNT ASSY. CORE	128-5	.185	3	.555	6.72	.60	6.12
MOUNT ASSY. CORE	128-7	.233	1	.233	4.16	1.04	3.12
MOUNT ASSY. CORE	128-9	.180	1	.180	3.22	.80	2.42
MOUNT ASSY. CORE	128-11	.191	1	.191	3.41	.85	2.56
RING - CORE LOCK	145-3	2.000	2	4.000	48.48	4.24	44.24
GUSSET - CORE LOCK	145-5,7	.030	8	.240	2.88	.24	2.64
SPACER	292-1	.036	18	.648	10.44	3.96	6.48
FIN - HEAT EX.	5-7218 031-0303	.0693	252	17.464	287.28	42.84	244.44
FIN - HEAT EX.	5-7218 040-0303	.0792	36	2.851	46.80	7.20	39.60
TUBE - INLET PAN	-100	2.74	1	2.74	56.43	7.53	48.90
TOTAL					1221.09	155.02	1066.07

TABLE 14 (Con't)

SHEET 2 of 2

APPENDIX A

MANUFACTURING COSTING METHODOLOGY

The methodology used in the development of manufacturing costs follows the standard cost estimating procedures used by Pioneer. This methodology is discussed below.

INITIAL EVALUATIONS

Manufacturing engineers analyze the part or assembly and list each of the manufacturing processes, or operations, required to complete the fabrication cycle from the raw material to the finished product.

DETAILED PROCESSING AND COST ESTIMATING

Process engineers and cost estimators, under the direction of manufacturing engineers, conduct a detailed process and cost analysis for each part and assembly. All information developed during this analysis is recorded on the form shown in Figure 1. The work flow chart presented in Figure 2 illustrates the methodology used to process the information and calculations required to develop the cost for a particular part or assembly. A process/cost sheet is made out for each part and subassembly in the total assembly. The results are summarized to obtain the total assembly cost.

Two costs are developed in this process, variable cost and manufacturing cost. The variable cost contains only those costs associated with the manufacture of the part or assembly. Manufacturing cost consists of the variable cost plus fixed burden costs.

An example of the processing and cost estimating process shown in Figure 1 is discussed in the following paragraphs. This is the manufacturing process sheet for forming a bumper face bar. The process sheet entries include all operations, from straightening the sheet steel to the final forming of the bumper.

The column headings on the process sheet are:

●OPER.	Each operation is coded in this column. For this part seven distinct operations are required and are coded 10 through 70.
●OPERATION DESCRIPTION	Each distinct operation is described.
●TYPE OF EQUIPMENT	Capital Equipment employed in each operation.
●M/P	Number of men required for each operation.

ESTIMATING DEPARTMENT OPERATION SHEET

DRAWING DATE

OPER	OPERATION DESCRIPTION (VOL. / P/A / REQ.)	TYPE OF EQUIPMENT	M/P	PCS/HR / MINS	LABOR COST / LABOR RATE	OCC HOURS		BURDEN RATE	BURDEN COST	VAR COST / MFG COST	DIE MODEL $(000)	TOOLING $(000)
10	Flex Roll & Apply Drawing	Flex		480	.1628		V	32.217	.0670	.2298	-0-	-0-
	Compound	Roll	4	.500	.3255	.00208	M	93.389	.1942	.3570		
20	Rough Blank	300 Ton		400	.0977		V	"	.0805	.1782	-0-	9
		Press	2	.300	.3255	.00250	M	"	.2335	.3312		
30	Draw (Use Automatic Unloader)	Toggle		400	.0488		V	"	.0805	.1293	7.5	72
		Press	1	.150	.3255	.00250	M	"	.2335	.2823		
40	Cam From Top & Bottom, Pierce Parking Lite	84x120"	2	400	.0977		V	"	.0805	.1782	-0-	62
	Openings & (9) Holes on Front Surface	SS Press		.300	.3255	.00250	M	"	.2335	.3312		
50	Cam Trim Both Ends, Flange (2) P/L	"		400	.0488		V	"	.0805	.1293	-0-	50
	Openings		1	.150	.3255	.00250	M	"	.2335	.2823		
60	Fin. Flg. (2) Openings, Pierce (2) Pkg. Slots			400	.0488		V	"	.0805	.1293	4.0	48
	& Cam Pierce, Bottom Attaching Holes		1	.150	.3255	.00250	M	"	.2335	.2823		
70	Finish Cam Cup Engs			400	.0977		V	"	.0805	.1782	4.5	43
			2	.300	.3255	.00250	M	"	.2335	.3312		
							V					
							M					
							V				Check Fixt. 10.5	
							M					
	NEXT OPER.						V					
	NEXT ASSY.						M					

SHT	COIL	GAGE	QUAL	MAT'L		PCS	ROUGH WT
X		121	DQ	HR	33" x 31" =	2	48.0724
				.950	Fine Grain		
							7.5522
					11.57# of Scrap	-	.1736
					.015 = .1736		7.3786
					Scrap Credit		

COST PER LB .1571 MAT'L COST 7.3786

PART NAME
FACE BAR - FRONT BUMPER (1) REQUIRED

SKETCH REMARKS VOLUME	TOOL COST
TRY-OUT	
	MACH. & FACILITIES
INSTALLATION	
FREIGHT	
HAND. EQUIP.	

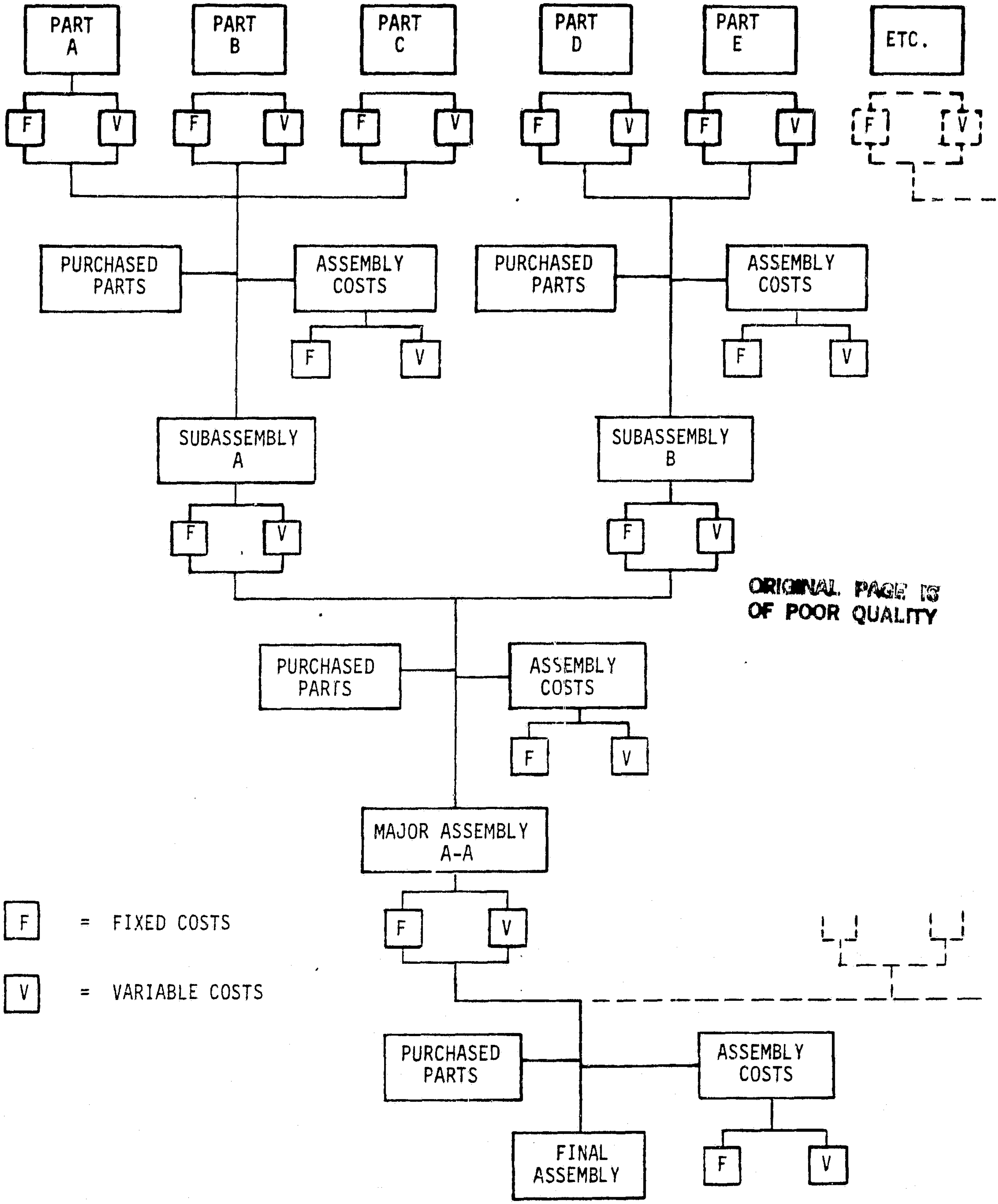
TOTAL VAR. LABOR & BURD		1.1523
TOTAL MFG. LABOR & BURD		2.1975
MATERIAL		7.3786
SCRAP	1%	.0738
SET UP		
OTHER		
MARK UP	10%	
TOTAL VAR. COST		
TOTAL TRANS. COST		

$26.5 $284

KEY ☐
NON KEY ☐
VOL.
UPC
PART NO.

T & FC / PP JOB NO. PEM-3-80-A PROCESS ENG DATE DEPT. NO.

Figure 15



ORIGINAL PAGE IS OF POOR QUALITY

Figure 16

●PCS/HR / MINS	PCS/HR is the pieces produced per hour per operation. MINS is the man minutes per piece for each operation.
●LABOR COST / RATE	LABOR COST is the direct labor per piece. LABOR RATE is the direct labor per minute (including fringes).
●OCC. HOURS	Is the hours each piece is in the capital equipment being used. For example, if the production rate is 400 pieces per hour, the occupancy hours is one hour divided by 400 pieces per hour or .0025 hours per piece.
●BURDEN RATE	Two entries for each process is shown. The entry V is the variable burden rate, which is the rate per capital equipment occupancy hour. The entry M is the manufacturing burden (including the variable burden). Again, this is the rate per hour of the capital equipment employed.
●BURDEN COST	Per piece burden cost is calculated by multiplying each burden rate by the occupancy hours.
●VAR COST / MFG COST	VAR COST is the variable burden plus direct labor cost. MFG COST is the cost of each operation including direct labor, variable burden and fixed burden.
VARIABLE BURDEN RATE	Includes Set-Up Costs; In-Bound Freight, Perishable Production Tools, and other Miscellaneous Costs that vary with volume changes.
FIXED BURDEN RATE	Includes Taxes, Insurance, Depreciation on Buildings, Depreciation on Capital Equipment, Maintenance and Repairs, and other Miscellaneous Costs that do not vary with volume.
MANUFACTURING BURDEN RATE	Includes Variable and Fixed Burden Rates.

●DIE MODELS — Unique die models required for each operation.

●TOOLING — Dies, fixtures and other special tooling required for each operation.

Material is noted and cost calculated in the special box located on the lower left corner of the sheet. Column headings in this area are self explanatory. Costs for producing the part are totaled in lower right side of the form.

The entries are:

(a) Total Variable Labor and Burden, i.e., direct labor plus variable burden.

(b) Total manufacturing Labor and Burden, i.e., direct labor, variable burden and fixed burden.

(c) Material; i.e., total material cost.

(d) Scrap; an allowance for scrap based on experience. (% of Var. Cost)

(e) Markup - Since this is a part involving inter-divisional transfer, a markup is included.

(f) Total Variable Cost is the sum of items (a), (c) and (d).

(g) Total Transfer Cost is the sum of (b), (c), (d) and (e).
This part is obviously a very high material sensitive part since approximately 70% of the transfer cost is reflected in the cost of steel.

All sub-assembly and final assembly cost will also be developed on these process sheets.

Figure 3 presents a flow diagram of the cost build-up of an individual component from basic cost items through consumer costs.

COMPUTER ALTERNATIVE

To permit more expeditious data processing, Pioneer has enlisted a computer program to make all of the calculations discussed above.

Using the computer requires that the manufacturing engineer process the part being costed, selected the equipment required, and define the operation cycle time. Figure 4 illustrates the process/cost sheet prepared by the manufacturing engineer for the computer. Note the equipment code specified for each operation. From this information

DETERMINATION OF MANUFACTURING AND CONSUMER COSTS

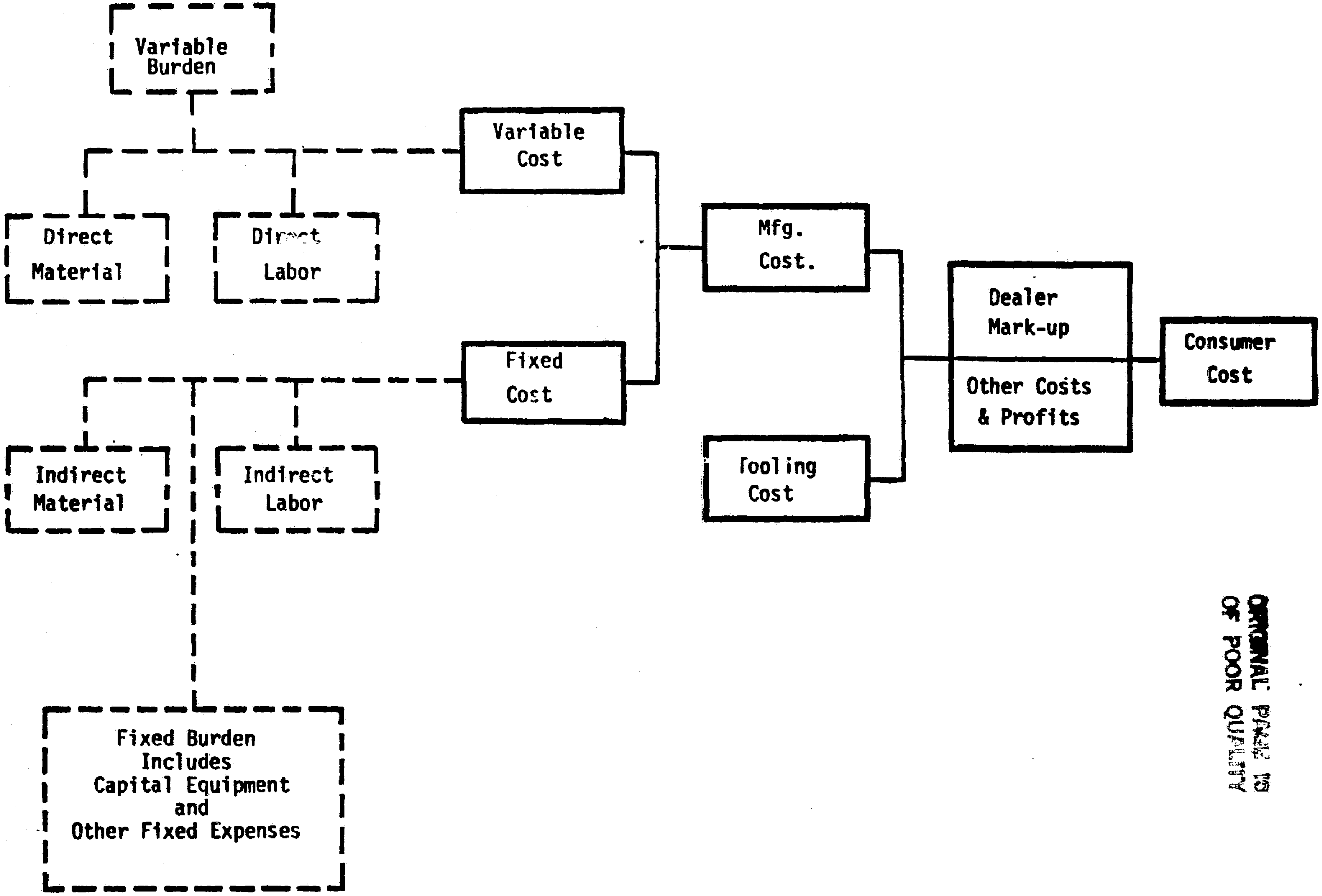


Figure 17

ESTIMATING DEPARTMENT OPERATION SHEET

DRAWING DATE N.A.

OPER	OPERATION DESCRIPTION VOL. 400,000 P/A 1 REQ. 400,000	TYPE OF EQUIPMENT	M/P	PCS/HR. / MINS.	LABOR COST / LABOR RATE	OCC HOURS		BURDEN RATE	BURDEN COST	VAR COST / MFG COST	DIE MODEL $(000)	TOOLING $(000)
10	ROUGH BLANK FROM SHEET	801					V					
	AUTO LOAD & EJECK		1	.12			M					
20	DRAW COMPLETE	801					V					
	AUTO LOAD AND EJECT		1	.16			M					
	TURN PANEL OVER						V					
	AUTO ROLLOVER FIXT.		0	.16			M					
30	TRIM BINDER STOCK - PIERCE LOCK	801					V					
	& HANDLE HOLES - AUTOLOAD & EJECT		0	.16			M					
40	FORM HEM FLANGE - 3 SIDES & BELT	801					V					
	FLANGE - AUTO LOAD & EJECT		0	.16			M					
50	FINISH FORM BELT FLANGE	801					V					
	AUTO LOAD & EJECT		1	.16			M					
							V					
							M					
							V					
							M					
							V					
							M					
							V					
							M					
							V					
							M					
							V					
							M					
	NEXT OPER.						V					
	NEXT ASSY.						M					

SHT	CON	GAGE	QUAL	MAT'L		PCS	ROUGH WT
✓		.032	DQ	CRS	34.9 x 52.7	1	16.64
					ZINCRO METAL		

COST PER LB .2935 MAT'L COST $4.91

PART NAME

DOOR - OUTER PANEL - IN/WHITE

SKETCH · REMARKS	TOOL COST	
VOLUME		
TRY-OUT		
	MACH. & FACILITIES	
INSTALLATION		
FREIGHT		
HAND. EQUIP.		

TOTAL VAR. LABOR & BURD	
TOTAL MFG. LABOR & BURD	
MATERIAL	
SCRAP 1%	
SET UP	
OTHER	
MARK UP 10%	
TOTAL VAR. COST	
TOTAL TRANS. COST	

KEY ☐

NON KEY ☐

VOL. ____

UPC ____

PART NO

DET NO.

T & FC / PP

JOB NO. 2?709

PEM-3-80-A

PROCESS ENG V/H

DATE 1-?7-81

Figure 18

ORIGINAL PAGE IS OF POOR QUALITY

the computer selects the appropriate labor and burden rates. Using the cycle time specified on the process/cost sheet for the given equipment code, the computer calculates the labor cost, occupancy hours, variable burden, and manufacturing burden. The scrap material cost are computed and the total cost is calculated. The computer format sheet is illustrated in Figure 19.

Use of the computer permits error free accumulation of the total cost of a product, eliminating manual build up of sub-assembly to final assembly costs. Other cost data manipulations and extractions are possible using the computer which are cost prohibitive if attempted manually.

PIONEER ENGINEERING

RTG005	PROJECT - 1D	MANUFACTURING COST ANALYSIS	17.00.05	PAGE 1 4/10/81

VOLUME- 400,000 P/A- 1

PART #- 1 DESC- DOOR - OUTER PANEL - IN/WHITE UPG-

OPER	OPERATION DESCRIPTION EQUIP	M P	STD MIN	LAB COST LAB RATE	OCC HRS	BURDEN RATE	BURDEN COST	VAR COST MFG COST	DIE MODEL	TOOL $000
010	ROUGH BLANK FROM SHEET AUTO LOAD & EJECT									
	8D1	1.00	.12	.0381 .3174	.0020 V	66.12	.1322	.1703	0	.0
020	DRAW COMPL. AUTO LOAD, EJECT & TURNOVER									
	8D1	1.00	.16	.0508 .3174	.0027 V	66.12	.1785	.2293	0	.0
030	TRIM BINDER STK. & PIERCE LK. & HDL. HLS									
	8D1	.00	.16	.0000 .3174	.0027 V	66.12	.1785	.1785	0	.0
040	FORM HEM FLANGE 3 SIDES & BELT FLANGE									
	8D1	.00	.16	.0000 .3174	.0027 V	66.12	.1785	.1785	0	.0
050	FIN. FORM BELT FLANGE COMPLETE									
	8D1	1.00	.16	.0508 .3174	.0027 V	66.12	.1785	.2293	0	.0

ANNUAL REQ-	400,000		LAB MIN -	.4400		0
MAT CODE -			LABOR $ -	.1397		.0
COST/LB -	.294		BURDEN V-	.8462		
SCRAP FAC -	.0%					
ROUGH WT -	16.69		SCRAP -	.0000	TOTAL VAR	5.8928
FINAL WT -	10.40	OTHER- .00	MATERIAL-	4.9069		

ORIGINAL PAGE IS OF POOR QUALITY

Figure 19